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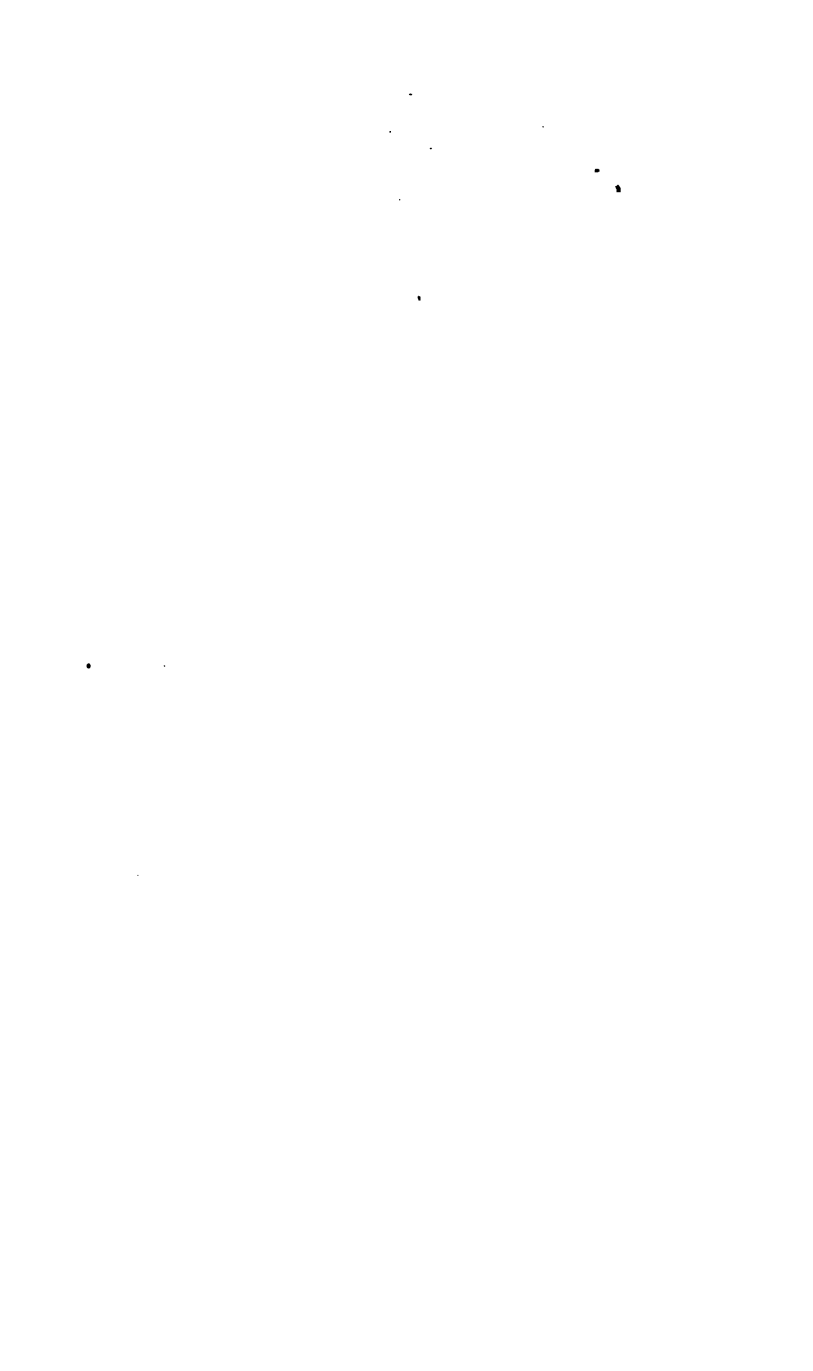
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**HOUSEHOLD CHEMISTRY;**  
**OR,**  
**RUDIMENTS OF THE SCIENCE**  
**APPLIED TO**  
**EVERY-DAY LIFE.**

**BY**  
**ALBERT J. BERNAYS, Ph.D., F.C.S.,**  
AUTHOR OF LECTURES ON AGRICULTURE, ETC.

**THIRD EDITION.**  
**CONSIDERABLY ENLARGED.**

**LONDON:**  
**SAMPSON LOW & SON, 47, LUDGATE HILL.**  
**1854.**

*143. 2. 3.*

C. RICHARDS, 100, ST. MARTIN'S LANE.



TO  
THE REV. L. J. BERNAYS, M.A.  
THIS LITTLE WORK,  
CONTAINING  
THE SUBSTANCE OF LECTURES DELIVERED AT ELSTREE SCHOOL,  
**Is Dedicated,**  
WITH MUCH AFFECTION, BY  
HIS BROTHER.



## PREFACE TO THE THIRD EDITION.

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THE fact of the sale, within less than two years, of two large editions of his little work, is sufficient evidence that there was a demand for a book of its character, which the author had endeavoured, as the result has shown, not quite unsatisfactorily to supply. Nevertheless, while most grateful for the kindness with which "HOUSEHOLD CHEMISTRY, OR THE CHEMISTRY OF EVERY-DAY LIFE," had been received by the press and the general public, the author conceived it to be his duty, in preparing for publication another edition, in the form he intended it finally to assume, to make it, as far as he could, more worthy of the favor it had hitherto enjoyed. The alterations which he considered it desirable to make, together with circumstances not within his control, have combined to delay the publication of this edition; but the author trusts that the delay has not been without advantage to his work. The whole has been revised, and the Appendix entirely rewritten; while the addition of numerous illustrations is calculated to render the book more popular and generally useful. Imperfect as the work undoubtedly remains, the author trusts it may be found a useful manual of the chemistry of common life.

DERBY, *June*, 1854.

## PREFACE TO SECOND EDITION.

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THE favor with which this little volume has been received by the periodical press, and the rapidity with which the first edition has been sold, relieve me of the necessity of apologising for its re-publication. To make it, however, more worthy of a kind reception, I have not only thoroughly revised it, but re-arranged it in many parts, and made such additions as to render it more useful to the tyro in chemistry. To increase its suitableness as a school-book, I have added questions to the end of every chapter. Still I repeat, that I do not offer it as a class-book to regular students of Chemistry. For such, the excellent introductions by Graham, Fownes, Brande, Liebig, Turner, Gmelin, &c., are all-sufficient. I have written chiefly for the young, and for those who, although people of general education, witness in the processes of daily life some of the most important chemical operations in themselves, and all that is done for their subsistence, without either knowing or heeding those great laws by which the Author of the Universe has produced and sustains His creation. To such, it was thought, an explanation of these chemical phenomena, in a familiar form, such as is usually adopted in lectures, would prove most advantageous. It might explain and clear up many things, remove many errors, and often supply hints for doing some things better and more effectually than they are usually performed, or remedies in cases of failures or accidents, which

otherwise might prove injurious or even dangerous ; and, here and there, encourage persons of sufficient talent and leisure to enter upon the serious study of a science, which offers such an abundance of amusement and instruction.

I have naturally availed myself of the labors of my predecessors and cotemporaries, as must necessarily be done in attempting to write on any science. I have even gone so far as to make use of the very words of others, if I thought I could gain nothing in precision and clearness by employing expressions of my own. I have, however, not failed to acknowledge the sources from which I have thus drawn, except in cases where the words had impressed themselves on my memory with the facts they had taught me, without my being able to remember the original mind to which I may be indebted for both. Any one acquainted with the works of some of our English Chemical writers, and of those of Germany, will understand what I mean.

The titles of the several chapters are imitated from Professor Liebig's "Chemistry of Food;" for, as far as I remember, I first thought of lectures under such titles after reading that beautiful work. When I first delivered the lecture on the "Chemistry of the Breakfast," some five years ago, the idea was suggested to me by the book just alluded to. The other chapters which make up "Household Chemistry," follow of necessity from the previous thought.

The name "Household Chemistry" was suggested to me by a clergyman, whose knowledge is only exceeded by his goodness, and whose friendship I have the honor to enjoy. The term was, no doubt, suggested by that admirable periodical, "Household Words," a serial worthy of the attention of young and old.

The Appendix contains a number of useful and



simple experiments, many of which may be understood and performed by a child of eight years old.

To those who, by the perusal of this book, may be induced to become students of Chemistry, I would recommend the Manual of Fownes. It is compact and accurate, and contains an immense amount of well-digested information.

In conclusion, I would add one word of caution. I should be sorry in any way to encourage a mere smattering of knowledge; but the experimental parts of Chemistry are so striking, that there is danger of their fixing the attention, to the exclusion of any consideration of the relations which subsist between the phenomena. It were as profitable to witness a display of fireworks, as thus to attend to chemical experiments. The penalty of the sweat of the brow is as much exacted for the enjoyment of knowledge as of that of the fruits of the field.

CHEMICAL LABORATORY, DERBY,  
*September, 1852.*

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# CHAPTER I.

## THE CHEMISTRY OF THE ATMOSPHERE.

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1. THE most intimate relations exist between the constituents of air, and those of plants and animals ; so intimate, indeed, that an intelligent knowledge of the varied properties of the air will enable us to understand a host of the phenomena which cross our daily path. By far the greater bulk of substances constituting the vegetable kingdom, such as water, starch, sugar, wood, gum, the various oils so remarkable for their odors, and the resins, are contained, in an elementary form, in the air : in the animal kingdom, also, with the exception of the bones, and the small portions of earthy matters pervading every liquid and solid part of the body, we find nothing which is not discoverable in another form in the atmosphere. The very life of plants and animals depends upon air, and the wholesomeness of the latter, upon the relations existing between the animal and vegetable kingdoms.

2. The ATMOSPHERE derives its name from the Greek *ἀτμος* (atmos) vapor, and *σφαῖρα* (sphaîra) a sphere or globe, because it envelopes the earth as

with a mantle, and accompanies it, as the earth revolves through space. It is also bounded in extent; but whether from cold, or from a limit to the expansibility of its particles, is not well ascertained. Being confined to the earth's surface by gravitation,\* we find it most dense near the level of the sea. The density of the air decreases rapidly as we rise above the surface of the earth; thus, at a height of three miles it is one-half the density of the air at the earth's surface, at six miles it is one-quarter, at fifteen miles  $\frac{1}{30}$  of that density. The chief part of the atmosphere is thus evidently always within twenty miles of the surface of the globe, although from very sufficient reasons it is supposed to extend only to a height of forty-five miles, in a state of perceptible density.

3. The air is as much a material substance as iron or water; it is therefore possessed of weight, as the following experiment will prove. If a glass tube, closed at one end, be partly filled with water, and inverted in a basin also filled with water, the fluid will not fall in the tube, but remain suspended at a much higher level than that of the water in the basin. This is owing to the pressure of the air

\* Gravity is the principle of solidity and attraction,—a force put forth by all bodies alike, but lessening with increase of distance. Gravitation causes a stone to reach the ground, when permitted to fall from the hand; it is also gravitation which leads the moon in its path round the earth, and both in their yearly course round the sun. In short, gravitation is the cause of that effect, to which we apply the term *weight*, from *gravitas*, weight; the weight of any substance being merely a measure of the attraction of the earth for it.

upon the water in the basin ; for, if the tube were perforated at the top, the pressure of the air would be exerted equally on the water in the tube and in the basin, and accordingly the water would fall to the same level. If the tube be of any length under thirty-three feet, filled with water and inverted, the pressure of the air upon the water in the basin will be sufficient to keep the tube full ; or, in other words, a column of air of a certain diameter is equal to a column of water of the same diameter, thirty-three feet in height.

4. If the air be exhausted from the tube by means of the air-pump, and the open end then placed under water, the water will be found to rush with violence up the tube, and so fill it. At the height of thirty-three feet then, the column of water becomes balanced by the atmosphere; any change in the pressure of which must, of course, be attended by a change in the height of the column of water. Such an instrument becomes therefore a *measurer of atmospheric pressure—a Barometer*, from  $\beta\alpha\rho\omicron\varsigma$  (baros) weight, and  $\mu\epsilon\rho\omicron\nu$  (metron) a measure. Water barometers (an example of which may be seen in the hall of the Royal Society's rooms) are inconvenient, in consequence of their length. If we can therefore find a heavy liquid to replace the water, the tube need not be so long. Now

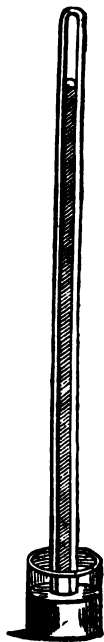


Fig. 1.

*quicksilver*, or *mercury*, happens to be thirteen and a half times heavier than water; the tube therefore requires to be but  $\frac{1}{13\frac{1}{2}}$  times as long. A column of mercury, thirty inches in height (or a column of water, thirty-three feet high), exactly counterbalances the average pressure of a column of air of equal diameter; in other words, the air presses upon the earth with a force equal to that of a layer of quicksilver thirty inches, or a layer of water thirty-three feet high.

5. A column of water in a tube thirty-three feet high, and standing upon a square inch of surface, weighs about fifteen pounds: therefore a column of air pressing upon a square inch, weighs likewise about fifteen pounds, because it has been shown to balance the water. Now the atmosphere presses equally in every direction: how great, then, must be the pressure upon all bodies, the following fact will prove. The surface of a man's body is about 2000 square inches; the pressure of the air upon it must be 2000 times fifteen pounds, or nearly fourteen tons! Such a force would crush the body to atoms, were it not opposed by the equal and contrary pressure of the air and other liquids within.

6. The vacant space above the quicksilver, in the closed end of the barometer-tube, is called the Torricellian vacuum, from its having been observed by Torricelli to be free from air.

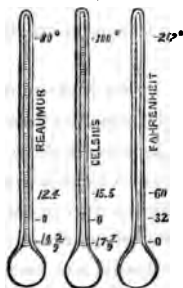
7. There are several modifications of the barometer, such as the syphon and wheel barometers; their action, however, is much the same as that which has been already described.

8. As regards the use of the barometer as a weather-glass, east and north winds usually cause the glass to rise; south and west to fall. The first-named are cooler, as they come from cold regions; and drier, because they pass over continents: while the latter come from warm regions into colder, and thus they lose some of their capacity for water, but as they pass over vast seas, they again attract much moisture. It therefore rains less frequently with north and east winds than with south and west. Wet and stormy weather is preceded by a fall of the mercury; fair and calm, by a rise.

9. The weight of one hundred cubic inches of air, at ordinary pressure (30") and temperature, has been computed at 31·0117 grains.

10. Temperature is ascertained by an instrument called a *Thermometer*. It is derived from two Greek words, *θερμός* (thermos) heat, and *μετρέω* (metreo) I measure. It does not show how much heat a body contains; but it points out a difference in the heat of various bodies. The thermometer gives the same kind of information which may be discovered by the feelings, viz.: the impression of heat or cold. All, therefore, that we learn from this instrument is, whether the temperature of one body is greater or less than that of another; and the difference is expressed by the *degrees* of the thermometer. The latter consists of a tube of a uniform small bore, having a ball blown at one end. The ball and part of the tube are filled with quicksilver (or sometimes spirits of wine), the air is expelled by boiling, and then the tube is closed. To obtain the degrees,

two fixed points are required, the boiling and freezing of water. The distance between these two points may be divided into any number of equal parts or degrees. Fahrenheit, a philosophical instrument maker, whose scale is commonly used, divided it into 180 degrees, beginning his scale at a point 32 of these degrees below the freezing-point of water, which is the *zero* of the scale. In France, the centigrade thermometer of Celsius prevails. He placed his zero at the freezing-point of water, and divided the distance between that and the boiling point into 100 degrees, whence the name centigrade.



Figs. 2, 3, and 4.

Reaumur, whose thermometer is employed in Germany, adopted the same starting-point or zero as did Celsius, but divided the distance between the boiling and freezing of water into 80 degrees only. Thus, the boiling-point of water on Fahrenheit's scale is 212, on the centigrade 100, and on that of Reaumur 80. In

order to compare these thermometers with each other, it need only be remembered that 4 degrees of Reaumur are equal to 5 of Celsius, and 9 of Fahrenheit. To express *degrees*, the sign  $^{\circ}$  is employed; to all above  $0^{\circ}$  or zero, the sign  $+$  is usually prefixed, to those below  $0^{\circ}$ , invariably the sign  $-$ .

11. The temperature of the air is greatest near the earth, because the air transmits the rays of light without decomposing them, and cannot therefore be

heated by them before they reach the surface of the earth, where they are decomposed, and their heat set free. The air, which thereby becomes warmed, ascends and mixes with the upper, colder strata. This is the reason why the atmosphere becomes colder as we ascend into it, until, even in the hottest summer season, its temperature sinks below the freezing-point. In the lower strata, this decrease of temperature has been found to amount to about 1 degree for every 352 feet of ascent, although at greater elevations the decrease is probably less rapid. This is also the reason why the temperature decreases in ascending high mountains, until, even in the warmest climates, the region of perpetual snow may be reached.

12. The ordinary temperature of the air is 60° F. In "Household Chemistry," all allusions to temperature are according to Fahrenheit.

13. As might be expected, the air is both tasteless and inodorous; were it otherwise, our sense of taste and smell would be comparatively useless. It is also perfectly transparent and colorless; but when viewed in masses, as in a clear sky, it presents a blue appearance. The color of the blue sky is probably peculiar to it; Brewster has shown that it is due to reflected light. The atmosphere must therefore have a disposition to absorb the red and yellow rays, and to reflect the blue. In consequence of the dark space beyond our atmosphere being seen through it more distinctly, the color of the air deepens in intensity the higher we rise; at great



heights, therefore, the sky has almost a black appearance. The gradual transition of the blue color into light blue, is owing to reflected light from vapor suspended in the air.

14. Atmospheric air consists chemically of a mixture of several gases. According to the latest experiments, one hundred volumes of air are found to contain twenty-one volumes of OXYGEN—so called from two Greek words, ὄξυς (oxus) acid, and γέννᾱω, (gennao), I produce, because formerly supposed to be the only acidifying principle. This gas is most abundantly diffused throughout nature, forming as much as eight-ninths of the weight of water, one-fifth of the weight of air, and nearly one-half of the weight of the solid rocks which constitute our globe. It is also largely contained in all animal and vegetable substances. Of the importance of oxygen too high an idea can scarcely be conceived. Neither respiration nor combustion can be carried on without it; in its absence no human being or animal can live, no candle or fire can burn. On these accounts, oxygen is also called VITAL AIR, from *vita*, life; and EMPYREAL AIR, from εἷν (en) in, and πυρ (pyr) fire. Water absorbs oxygen; hence it is always found in rain, snow, spring, and river water. The oxygen contained in rain, as it trickles through the soil, ministers to the growth and nourishment of plants in various ways. It exerts a very powerful influence upon some of the constituents of the soil, rendering them soluble in water, and is the cause of the decay and putrefaction of

vegetables. It has neither color, taste, nor smell; and is always gaseous, when not combined with other matters. It does not change the color of flowers. Its specific gravity\* is greater than that of air, being as 1·111 to 1·000.

15. Oxygen is an *element*; a term by which we understand such a form of matter as has hitherto resisted all attempts to decompose it, or to separate it into simpler forms.

16. Finally, oxygen possesses most powerful attractions for other bodies. When a substance unites with oxygen, it is said to *oxydize*; the act of combination is called *oxydation*. Oxydized bodies are

\* It may be as well to explain what is meant by the term. It is obvious that different pieces of the same substance will vary in *weight*, according to their size; but a small piece of gold will weigh much less than a large piece of cork, which would really be lighter, if the two were of exactly the same magnitude. In all scientific investigation of substances, it is highly important to know what would be their *relative weights*, if they were of the same magnitude; or, what is still more convenient, their relative weight compared with some accepted standard. Thus, PURE WATER, of a certain temperature, is the *standard* whereby to compare the weights of *liquids* and *solids*; AIR the *standard* of comparison between the weights of *gases*. If we compare a mass of iron with a mass of water of exactly the same size, and suppose the water to weigh 1, the iron will be found to weigh 7·8, or nearly 8 times as heavy. *These numbers represent the specific gravities of iron and the standard of comparison, water*; because if equal pieces of them of any other size were taken, their *relative weights* would be the same, though their absolute weights would be less or greater than those of the first pieces, according as they were smaller or larger. To obviate the necessity of reducing a new substance to precisely the same size of another,

divided into two classes: *acids* and *oxides*. The former division includes those compounds which possess the general properties of acids; and the latter comprehends those which not only do not possess that character, but yield salts by uniting with acids.

17. But oxygen also exists in the air in another form. Wonderful as are the oxydizing properties of free oxygen, they sink into insignificance when compared with oxygen in a *nascent* state. By this term, we mean oxygen slowly liberated from water or some other of its compounds, by natural or artificial processes. The discovery of nascent oxygen in air is due to Professor Schoenbein, of Bâle, in

for the purpose of comparing their weights, we adopt the following plan. If we immerse a piece of a substance, no matter what be its form, in water, it will displace a quantity of water exactly equal to itself in bulk. The substance so immersed is, in some measure, supported by the water pressing upwards against its under side; it consequently loses weight, proportioned precisely to the bulk of water displaced by the substance. Hence, if the *water* be assumed as the *standard*, by weighing a body first in the air, and then again when immersed in water, the difference of the two weights is the weight of a body of water precisely equal in bulk to the body. By these means, the specific gravity of the body, or its relative weight, as compared with the standard, is ascertained.

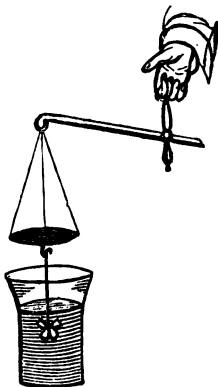


Fig. 5.

Switzerland. He calls it **OZONE** (from  $\omicron\zeta\omega$  (*ozo*), I yield odor), because he has proved it to be identical with the peculiar matter evolved from the electrical machine, and known as the electric smell. That ozone is extensively formed in nature, will be evident when we reflect upon certain of its properties. It is nature's great bleaching and disinfecting agent. Although there are doubtless other processes, electricity may be said to be the main agent in the formation of ozone. The amount of it in the air, though generally so small as not to manifest its presence by its smell, is ever varying. Nevertheless, there is good reason to believe that this modified oxygen plays an important part in the purification of the air, and in the phenomena of health and disease.

18. Mixed with the vital air, the atmosphere is found to contain, in every hundred volumes, seventy-nine volumes of another gas, called **AZOTE** or **NITROGEN**. The name azote (from  $\alpha$ , privative, and  $\zeta\omega$ , zoe, life), was given to it on account of its inability to support life; and it was called nitrogen, as being a constituent part of nitric acid. Like oxygen, it is an element, has neither color, taste, or smell, nor any action upon vegetable colors. Unlike oxygen, it does not support respiration or combustion. Nitrogen is rather lighter than atmospheric air, compared with which its specific gravity is as 0.972 to 1.000. It is a constituent of many vegetable and of most animal substances; indeed, no kind of food can be considered nutritive, or, at least, capable of forming flesh and blood, unless

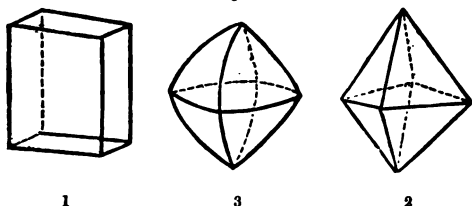
nitrogen forms a part of it. Although it will not support respiration, the fact of its forming so large a portion of the air, proves its harmlessness. We are doubtless unacquainted with many of its uses; but we know that its presence in the atmosphere is essential to temper the effects of oxygen upon the system, for pure oxygen, if inhaled by a human being or an animal for any length of time, will cause inflammation, and ultimately death. Nitrogen manifests so few and such feeble attractions or affinities towards oxygen and other bodies, that it is eminently adapted for admixture with other gases.

19. Another important constituent of the atmosphere, although, however, very small in amount, is CARBONIC ACID, called also *fixed air*, or *choke-damp*. According to the most recent experiments, one hundred volumes of inland air, contain, on an average, 0.05 volumes of carbonic acid gas. The air on mountains contains more carbonic acid than that of low lands, probably because in the higher regions the air meets with fewer plants, and the carbonic acid is less likely to be absorbed by moisture. The maximum quantity of carbonic acid in the atmosphere is found towards morning; the minimum, at the close of day. Its sources are very numerous. At every respiration of men and animals, a portion of the *Carbon* of the blood unites with the oxygen of the air, and forms carbonic acid. The combustion of wood and coal, the processes of decay, fermentation, and putrefaction, are also largely productive of this gas. Whenever carbon unites with

oxygen at high temperatures, carbonic acid is always the result.

20. This constituent of the atmosphere is, then, a compound body—a compound of oxygen with another element, CARBON. That rare and beautiful gem, the *diamond*, consists of pure carbon. It crys-

Fig. 6.



tallizes in *cubes* (1) as well as *octohedrons*, (2) the octohedral crystals presenting often a peculiar appearance, from the rounding of the edges, (3) which give almost the form of a sphere to it; is generally colorless and transparent, of greater hardness than any other known substance, peculiarly lustrous, and, like oxygen and nitrogen, a non-conductor of electricity. Its specific gravity is greater than that of water, being no less than 3.52. Heated to redness in an atmosphere of pure oxygen, the diamond unites with it, burns quickly away, and forms carbonic acid. *Plumbago* is also a species of carbon. It is so soft, and imparts its color so readily to other bodies, that it is used in making (lead) pencils, whence its other name, *graphite*, from the Greek, γραφειν (*graphein*), to write. From its similarity to lead, and the black polish it gives to stoves, it is also called *black lead*. But, besides these two forms

of it, carbon is to be met with in great abundance, both in the animal and vegetable kingdom. Coal, charcoal, coke, and soot, consist mainly of carbon; indeed, it is to be found in nearly all the materials employed in the production of artificial light and heat.

21. For the purpose of forming an idea of the quantity of carbonic acid given off to the air in a single place, it may be mentioned that in London and its suburbs two million tons of coal are annually consumed, the combustion of which requires upwards of four million tons of oxygen, which must be provided by the atmosphere. To this carbonic acid, resulting from the union of the coal with oxygen, must be added that produced by the burning of so many gas-lights, candles, &c. Again, there are congregated in the metropolis upwards of two million of human beings, each of whom will, on an average, daily supply four pounds of carbonic acid to the atmosphere; and if to this be added the production of this gas,—the result of respiration, from horses and other animals, and from the processes of fermentation in breweries and distilleries, it will appear that London alone supplies the enormous quantity of eleven millions of tons annually to the atmosphere.

22. Carbonic acid, then, is of very frequent occurrence. At ordinary temperatures it is a colorless gas, incombustible, and does not support the combustion of most other bodies. Although one of the weakest acids, it communicates a red color to

blue litmus\* paper, and combines with oxides, forming a class of salts called *carbonates*. Thus, for example, it has great affinity for lime, with which it readily combines, and forms carbonate of lime. It has a slightly irritating odor; and when inhaled pure, or even largely admixed with air, causes death. Water, at ordinary temperature, absorbs its own volume of this gas, but much more under pressure. Upon this principle soda-water is made, which consists simply of water into which carbonic acid is forced by pressure. What is usually termed effervescence (from *effervescens*, boiling), is produced by the rapid escape of this gas, as in champagne, ginger-beer, ale, and porter. Its specific gravity is far greater than that of air, being as 1.525 to 1.000. It is therefore liable to accumulate in such holes and caves of the earth where it may happen to be generated; and even in rooms not properly ventilated. In close rooms the oxygen of the air is, by the process of respiration, converted into carbonic acid; and the atmosphere would soon become unfit for breathing, were it not for the change of air which takes place through the crevices of doors and windows. Since, then, carbonic acid is of such frequent occurrence, being always present in the air, and being constantly formed at the expense of the oxygen of the latter,—how is it,

\* Litmus or Orchil, so much used as a delicate test for the presence of acids, which immediately change its blue color into red, is prepared by boiling a lichen—the *Rocella tinctoria*—in water. Strips of white blotting-paper, dipped into such a solution, and dried, form the litmus paper.



it may be asked, that the quantity of oxygen does not unduly diminish,\* and the carbonic acid increase to a most injurious extent?

23. This question, the solution of which is most important, is intimately connected with another,—namely, whence do plants obtain their carbon? The most simple experiment will prove the presence of carbon in the vegetable kingdom. If we char a piece of wood, a stalk, a leaf, or a piece of dry potato, the carbon becomes manifest, and appears as a black substance like charcoal. This substance is impure carbon. It may, perhaps, be assumed that carbon, being an elementary substance, cannot be produced by the plants themselves, but must be derived by them from surrounding substances. Now the chemical phenomena of vegetation are accomplished by the concurrence of the elements of the *air*, of *water*, and of the *soil*. A *seed*, with reference to its organization, consists of



Fig. 7.

an *embryo*,<sup>a</sup> (which includes the germs of the root and of the stem), and of the *cotyledon* or *cotyledons*,<sup>b</sup> which form the bulk of the seed. All seeds contain starch and gum, a substance (as in peas and beans) resem-

bling cheese, oily matters, and a certain small portion of ashes; which latter may be seen, if the seed be burnt.

\* According to a calculation of the illustrious Faraday, no less than 7,142,857 tons of oxygen are daily required in the economy of nature.

24. If some seeds be moistened, and placed under a glass containing common air, all the signs of germination will soon be perceived. On examination of the air, after a few days, it will be found to be altered in its composition; a portion of its oxygen has disappeared, and a corresponding volume of carbonic acid has been produced. Now, we know that seeds will not germinate in an atmosphere deprived of oxygen, and that the process of germination is always accompanied by the formation of carbonic acid. Germination and respiration are therefore alike in this property. Some seeds are known to germinate under water; this is owing to the constant presence in the water of atmospheric air in a state of solution. The larger the quantity of oxygen which immediately surrounds the germinating seed, other conditions being the same, the greater will be the quantity of carbonic acid generated in a given time. Oxygen is as favorable to germination as the presence of large quantities of carbonic acid is unfavorable; and the process will be manifestly hastened, by placing lime near the seed, in order to absorb the carbonic acid as fast as it is formed. The seed at first loses in weight from this formation of carbonic acid; but, as germination advances, and the roots and stem acquire size and shape, the increase of mass becomes very considerable. A seed of beet-root, of the weight of  $\frac{1}{100}$  of a grain, may produce a root weighing twenty-eight pounds. Now, without denying the influence of the soil upon the growth of a plant, it is a well-attested fact, that a seed may give birth to a plant, nay,

arrive at perfect maturity, by the mere concurrence of water and air.

25. Carbon is the predominating principle in dried plants, and is met with in the atmosphere in the form of carbonic acid. Plants, *under the influence of solar light*, are capable of decomposing this carbonic acid; its carbon unites with them, and its oxygen is restored to the air. The researches of de Saussure show the necessity of the presence of light in making the carbonic acid act favorably upon vegetation. He found that young plants, under the influence of solar light, decidedly thrived when the atmosphere contained as much as  $\frac{1}{11}$  of carbonic acid, and that their growth was evidently more vigorous than when in common air alone; and, at the conclusion of one experiment, he found almost the whole of the carbonic acid replaced by oxygen! He discovered further, that the smallest addition of carbonic acid to the air, above its ordinary quantity, is injurious to plants in the shade. At night time the assimilation of the carbonic acid ceases: oxygen is no longer exhaled from the leaves of the plants, but a true chemical process commences. Oxygen is inhaled by the leaves, and carbonic acid formed at the expense of the carbon contained therein; and this acid is retained, either in part, or wholly, in proportion as the green part of the leaf is more or less plentifully provided with water.

26. Here, then, we find the solution of the question, how it occurs that the proportion of oxygen in the atmosphere has remained unchanged in the lapse of ages. We find the life of plants connected with

that of animated nature in the most simple manner, and for the most wise purposes. The vegetable world not only affords the means of nutrition for the growth and continuance of animal life, but also separates the noxious carbonic acid from the atmosphere, and is an inexhaustible source of pure oxygen, supplying to the air the loss constantly sustained by it in the support of the animal creation. As, therefore, animals *exhale* carbonic acid, whilst plants *inspire* it, the composition of the atmosphere, the medium in which both live, remains unchanged.

27. WATER, also, is ever present in the atmosphere. In the state of *vapor* it exercises a most important influence on the health of human beings and animals, and on the growth of plants. At all temperatures water rises by evaporation into the air, which, therefore, is constantly impregnated with it; it accompanies the air wherever it penetrates, it pervades the pores in the leaves of plants, and gains admission into the lungs and skins of animals. The quantity of vapor which the atmosphere is capable of holding, is dependent upon temperature. When fluid water is present with vapor in large proportions, the latter becomes completely moist and opaque, as in *mist* and in *clouds*. (The red and golden tints of clouds appear to be owing to a peculiar property of steam. When steam issues into the atmosphere from under a pressure of from five to thirty pounds on the inch, a light appears of a deep orange-red color. The steam possessing this color is mixed with air, and on the point of condensation.) When the temperature of a cloud,

containing vapor in large quantities, falls, a portion of the vapor is condensed, and falls in the form of *rain*. When clouds form at temperatures below 32°, the watery vapor is converted into small needle-like crystals, which re-unite with many others, and fall as *snow*. The phenomenon of *hail* also is caused by cold, but under different circumstances. Its formation is always attended by electricity, and it seems to be produced in a moist ascending current of air (greatly cooled by rarefaction), having an upward velocity sufficiently strong to sustain the falling hailstones, until they have attained considerable size.

28. As to the exact nature of fog, much difference of opinion exists. There is no doubt it is caused by the separation of moisture from the air, but whether in the form of hollow globes of water, or as solid globules, is not well ascertained. London fogs are mixed with soot, and the various compounds resulting from the combustion of coal. These, together with the emanations from its million inhabitants, &c., render such fogs peculiarly unpleasant.

29. From the preceding remarks, it must be obvious that it is owing solely to the high temperature of the air that the presence in it of water is not always perceptible; for, if a portion of air be cooled, the water therein becomes manifest. Thus, if a decanter filled with spring-water, fresh from the well, be brought into a room, the outer surface of the decanter will immediately become covered with *dew*, because the cold decanter deprives the surrounding air of the heat necessary to retain its

water in invisible solution. And so generally the appearance of dew always follows a fall in the temperature of the substances on which it is deposited. All bodies on the earth's surface throw out heat in straight lines, every warmer to every cooler body; and thus the tendency of the surface of the earth is always towards a cooler state. When the sun shines, a body receives more rays than it sends out; its temperature, therefore, rises: when a body gives off more rays than it receives, as is the case on a cloudless night, its temperature falls; and thus the cooling of bodies occasioned by nocturnal radiation is always accompanied by a deposit of moisture upon their surface, in the form of minute globules; in fact, by a fall of DEW.

30. In very warm climates, the dew is so plentiful as materially to assist vegetation. When the sky is clear and calm, plants cool down during the night, and very soon show a temperature inferior to that which surrounds them. No dew is deposited on cloudy nights, as the rays thrown off by the earth are returned by the clouds, and the temperature of the air is consequently maintained. Nor does dew fall equally upon all bodies. "Different substances are endowed with the property of radiating their heat, and of thus becoming cool, with different degrees of rapidity; and those substances which in the air become cool first, also attract first and most abundantly the particles of falling dew. Thus, in the cool of a summer evening, the grass-plot is wet, while the gravel-walk is dry; and the thirsty pasture and every green leaf are drinking in the

descending moisture, while the naked land and the barren highway are still unconscious of its fall. How beautiful is the contrivance by which water is thus evaporated, or distilled, as it were, into the atmosphere—largely, perhaps, from some particular spots—then diffused equably through the wide and restless air, and afterwards precipitated again in refreshing showers or in long mysterious dews! But how much more beautiful the contrivance by which the dew selects the objects on which it delights to fall; descending first on every living plant, copiously ministering to the wants of each, and expending its superfluity only on the unproductive waste.”—*Johnston's Agr. Chem.*

31. Nocturnal radiation is frequently destructive to vegetation in spring and autumn, by lowering the temperature several degrees below the freezing point: for when the cooling of the earth's surface descends below  $32^{\circ}$ , the dew appears as frost. An unclouded sky affords the principal condition for nocturnal radiation. Before we had attained to the knowledge that bodies on the surface of the earth, on a clear night, become cooler than the surrounding air, it was difficult to comprehend how the flimsy coverings, which gardeners throw over vegetables for their protection from injury consequent on a low temperature, could be effective. The natives of Peru, having observed that it freezes only when the sky is clear and calm, contrive to create *artificial* clouds, when they are led to apprehend a frost. They set fire to heaps of damp straw, and thus raise a cloud of smoke over their crops—a

measure which Boussingault states to be a complete protection.

32. Water was for ages regarded as an element. Not longer ago than 80 years, it was thought possible to convert it into an earth; and we owe the correction of this error to the great French chemist, Lavoisier. In 1781, Cavendish and Watt first showed the compound character of water.

33. There is an element, HYDROGEN,—so called from two Greek words *ὕδωρ* (hudor) water, and *γενναειν* (gennaein) to generate, which, when inflamed in contact with air, produces *water*: the latter being a chemical combination of oxygen and hydrogen. The compound which contains hydrogen in the greatest abundance is water, of which it forms one-ninth by weight. It exists further as water of crystallization in crystals, and as a constituent of innumerable vegetable and animal bodies. Hydrogen is always prepared from water: when pure, it is a colorless, tasteless, and inodorous gas. Its specific gravity is 0.693; it is therefore  $14\frac{1}{2}$  lighter than air, and may be used for inflating balloons. Although very inflammable, it does not support the combustion of other bodies; nor is it known to exist in nature in a free state.

34. Hydrogen cannot be inhaled in a state of purity. In this respect it is like nitrogen. Not that hydrogen is poisonous; but, inasmuch as oxygen is essential to life, and is thereby prevented from entering the lungs, it becomes injurious.

35. If two volumes of hydrogen be mixed with one volume of oxygen, no combination ensues. But,



the flame of a burning body, the electric spark, or a red-hot coal, are sufficient to induce rapid combination; a violent report is heard, and water results. On account of the property of such an admixture of oxygen with hydrogen, to explode on the approach of flame, it is called *detonating gas*, or *explosive gas*.

36. To water and carbonic acid, whose presence in the air is constant, though small in quantity as compared with oxygen and nitrogen, must be added yet another substance, AMMONIA, in combination with carbonic acid, as CARBONATE OF AMMONIA. It owes its name ammonia to *sal-ammoniac*. This salt the Romans derived exclusively from Ammonia, a district of Lybia, in Africa, where an Egyptian god, Amun, was worshipped. It is called *harts-horn*, because it was first prepared from harts' horns: its odor is familiar to all as that of smelling-salts. It is a definite compound of nitrogen with hydrogen. At the ordinary temperature of the air, ammonia is a colorless gas, possessed of a pungent, exciting, and enlivening odor. It is feebly combustible, but does not support the combustion of other bodies. Animals die when immersed in it. Red vegetable colors are turned blue by it. The gas is very soluble in water; one measure of the latter will absorb as much as 680 measures of the former. The thus-formed liquid ammonia of the shops is possessed of all the pungent properties of the gas. Nor does it lose these properties when combined with carbonic acid, for carbonate of ammonia still emits a pungent smell. In the atmo-

sphere, however, it is contained in such minute quantities, that it is never known to communicate even the faintest odor to it. According to Fresenius, one million parts of air contain only 0.283 parts of carbonate of ammonia by day, and about twice that quantity by night. The comparative smallness of the quantity present by day is probably owing to two causes: 1, that in the daytime more ammonia is expended in the nutriment of plants; 2, that the ammonia which accumulates during the day and night together, is dissolved and precipitated by the dew at sunrise. Be this as it may, it is certain that the ammonia of the air does supply wild plants with much of the nitrogen required for their growth. It is well known that in the process of decay and putrefaction, ammonia is constantly evolved from all vegetable and animal matters containing nitrogen. We know, also, that salts of ammonia are products of the combustion both of wood and coal. From many sources, and at all times, ammonia rises into the air, and plays an important part in vegetable nutrition. It is certain that salts of ammonia have not only been discovered in the juices of many plants, but that the roots are capable of taking them up. And it is equally certain that guano, and such-like manures, owe much of their value to the large amount of ammoniacal salts which they contain.

37. In addition to OXYGEN, OZONE, NITROGEN, CARBONIC ACID, CARBONATE OF AMMONIA, and WATERY VAPOR, all of which must be regarded as constantly present, we find the atmosphere capable of admixture with certain accidental impurities,

which are dependent upon locality. Thus, near and above the sea, the air is always found to contain COMMON SALT, and indeed all the other components of salt water. NITRIC ACID also appears to be formed in the air, especially during thunder-storms. In the Tropics, electrical discharges are constantly taking place in the clouds; and this is probably the origin of a great portion of the nitric acid which is found on the surface of the earth in the form of nitre, nitrate of potash, or saltpetre. Many observers have proved the presence of nitric acid in the rain of thunder-storms; and the author has witnessed the blue flower of the hare-bell changed into bright red during a thunder-storm,—a result attributable only to the formation of nitric acid.

38. In large cities, the air is also contaminated more or less by the various gases evolved in the different processes of decay and putrefaction, and by the chemical operations carried on in such places. Their name is legion. Of these, the most injurious to health, as well as the most offensive to smell, is SULPHURETTED HYDROGEN gas, a compound of sulphur and hydrogen. It escapes frequently from drains and sewers, and is a constant accompaniment of the gas manufacture. Its smell is similar to that of putrid eggs, and it communicates its offensive taste and odor to many natural springs. So fatal is this gas to animal life, that its presence in air to the amount of only  $\frac{1}{1500}$  of its bulk, is destructive of the life of a small bird; and a horse dies in an atmosphere containing  $\frac{1}{250}$  of its volume.

39. Minute quantities of such gases are the cause of contagious diseases; and although in a work like "Household Chemistry," it would be out of place to investigate their character, they are well deserving of notice, as upon their presence in the air depends much of the physical misery of mankind.

40. But setting aside such trifling differences as are occasioned by the presence of various impurities, how is it that, as regards its chief constituents, the air maintains its composition so constantly? All experimentalists agree in this, that specimens of air brought from districts the most remote—from London and from New York, from Mont Blanc and from Chimborazo—preserve an absolute identity of composition. The principal difference is in the quantity of watery vapor; this, however, it would be natural to expect. But when we consider that the atmosphere is a mere *mixture* of gases, that no *affinity* whatever exists between its various constituents, that all bodies which possess attraction or affinity for oxygen combine as easily with it as if nitrogen were not present, that every passing rain removes those gases which are the most soluble; further, when we remember the still more remarkable fact, that all the gases contained in the air are of different specific gravities, that there is as great a difference between the weights of nitrogen and carbonic acid, as of oil and water, we are lost in amazement at the Power which can control such apparent contradictions.

41. Now these difficulties may be explained upon

the principle of what is called the *law of diffusion of gases*. This law (known as Graham's law) is found to be entirely independent either of specific gravity or affinity, and may be thus briefly stated: the particles of one gas, though highly repulsive to each other, do not repel those of a different kind; hence one gas acts as a vacuum with respect to another.

42. Were it not for this law, the carbonic acid evolved in such vast quantities in our large towns, would, from its own intrinsic weight, collect, and speedily destroy their inhabitants. The foul and noxious gases which constantly arise from the numerous operations of a large city, would spread disease and pestilence around it. Were it not for this law, the perfume of flowers, and the sweet scent of newly-mown hay, would not arise to fill our hearts with a sense of gladness; but would fall from their own weights on the senseless earth. Were it not for this law, the oxygen would separate from the nitrogen, and a universal conflagration, which no water could subdue, would arise on the ignition of the first fire. In fact, but for this law, there could be no life. Vegetation must languish and die, for want of a supply of carbonic acid, which, by this provision, is wonderfully and completely diffused throughout all the particles of air. The watery vapor, of no less importance, would not, as now, keep flexible the skin of animals, and supply parched vegetation with rain and dew. In the process of respiration, the minute cells of the lungs, in which the aëration of the blood takes

place, would not, as now, be emptied at each exhalation of the heavy carbonic acid which they contain ; but the process would, after a few minutes, be suspended, and death must inevitably ensue.

It is, indeed, a most necessary and beneficent law, and is well calculated to fill our minds with awe at the power, and gratitude for the goodness of that God, who, in the language of the patriarch, "bindeth up the waters in His thick clouds, and the clouds are not rent under them."

To sum up in the words of an eloquent writer in a recent number of the "Quarterly :"—" The atmosphere rises above us with its cathedral dome, arching toward the heaven, of which it is the most familiar synonyme and symbol. It floats around us like that grand object which the Apostle John saw in his vision—' a sea of glass like unto crystal.' So massive is it, that when it begins to stir, it tosses about great ships like playthings, and sweeps cities and forests like snow-flakes to destruction before it. And yet it is so mobile that we have lived years in it, before we can be persuaded it exists at all ; and the great bulk of mankind never realise the truth, that they are bathed in an ocean of air. Its weight is so enormous that iron shivers before it like glass, yet a soap-bell sails through it with impunity, and the tiniest insect waves it with its wings. It ministers lavishly to all the senses. We touch it not, but it touches us ; its warm south wind brings back color to the pale face of the invalid ; its cool west winds refresh the fevered brow, and make the blood mantle in our cheeks ; even its north blasts brace

into new vigor the hardened children of our rugged clime. The eye is indebted to it for all the magnificence of sunrise, the full brightness of mid-day, the chastened radiance of the gloaming, and the clouds that cradle near the setting sun. But for it, the rainbow would want its triumphal arch, and the winds would not send their fleecy messengers on errands round the heavens; the cold ether would not shed its snow feathers on the earth, nor would drops of dew gather on the flowers. The kindly rain would never fall, hail-storm nor fog diversify the face of the sky. Our naked globe would turn its tanned, unshadowed forehead to the sun, and one dreary monotonous blaze of light and heat, dazzle and burn up all things.

“Were there no atmosphere, the evening sun would in a moment set, and, without warning, plunge the earth in darkness. But the air keeps in her hand a sheaf of his rays, and lets them slip but slowly through her fingers; so that the shadows of evening gather by degrees, and the flowers have time to bow their heads: and each creature space to find a place of rest, and nestle to repose. In the morning, the garish sun would at one bound burst from the bosom of night, and blaze above the horizon; but the air watches for his coming, and sends at first but one little ray to announce his approach, and then another, and, by and by, a handful; and so gently draws aside the curtain of night, and slowly lets the light fall on the face of the sleeping earth, till our eyelids open, and, like man, she goeth forth again to her labor until the evening.”

## QUESTIONS ON CHAPTER I.

1. What use is there in a knowledge of the atmosphere? With what exceptions are the various products of the animal and vegetable kingdom contained in the air? In what form are they contained?

2. What is the origin of the word atmosphere? Why is it so called? Has the air a limit? By what force is the air confined to the earth? What is the meaning of gravitation? Give some instances of its power. Is the air equally dense throughout? In what proportion does its density diminish? Within how many miles of the earth is the greatest proportion of the air? How many miles does air extend to?

3. Is the air a material substance? By what simple instrument can you prove that the air exerts pressure? Of what height must the tube be?

4. What is the name of the instrument which shows the pressure of the air? What Greek words give it a name? How much heavier than water is quicksilver? State something about the pressure of the air in other words.

5. How much pressure does the air exert upon every square inch of surface? How many square inches of surface are comprised in the body of a man? How many tons weight does he carry about him? Why is he not crushed?

6. What is the name of the air-free space in the barometer-tube?

7. Are there any modifications of the barometer?

8. Of what use is it as a weather-glass?

9. What is the weight of 100 cubic inches of air?

10. How is temperature ascertained? What is the name of the instrument derived from? What kind of impression does the thermometer convey? In what does a thermometer consist? How many thermometers are there in common use? In which countries are they used? How can you compare their degrees?

11. Where is the temperature of the air greatest? Why? Why is the air colder, the higher we ascend? By how many



degrees does the temperature decrease? In how many feet? Is the region of eternal snow ever reached in warm climates?

12. What is the ordinary temperature of the air? What scale is employed in this work?

13. Has the air taste or smell? Has it usually color? When has it? To what is the blue color owing? Why does the color deepen as we rise in the air? Why is the color less near the earth?

14. Is the atmosphere a compound or a mixture? What is the name of the most important chemical constituent of air? From what Greek words is the name derived? To what extent is it contained in air? Prove its abundant diffusion throughout nature. What functions is oxygen necessary to? Hence what other names? Their derivation? State the physical (from *φύσις*, *phusis*, nature) properties of oxygen.

15. What is an element? Why is oxygen an element?

16. When bodies combine with oxygen, what are they said to do? How many classes of oxides are there? What distinguishes them from one another?

17. Can oxygen exist in any other form? How? What is the name given to modified oxygen? Why? Who discovered it? What is its use? How is it formed? Is there much of it in the air? Has it any probable connection between health and disease?

18. What other gas is present in very large quantities besides oxygen? How much? Whence its name? In what respects does it resemble oxygen? How does it differ? Is there any use for it in food? What are the objects of its presence in air?

19. What other important gas is contained in air? How much of it? When do we find most? When least? What are its sources? When is carbonic acid produced?

20. Of what is carbonic acid a combination? What is the chemical name of pure carbon? What are its properties? What is its specific gravity as compared with water? Name some other forms of carbon? What composes black lead?

21. Give from memory some notion of the amount of carbonic acid contributed to the air by London alone.

22. What are the properties of carbonic acid? What color

does it give to blue litmus-paper? What is litmus-paper? What are combinations of carbonic acid called? Is carbonic acid a poison? How much of it does water absorb? What do we usually understand by effervescence? What is the specific gravity of carbonic acid? Is it liable to accumulate in holes where it is formed in the processes of decay? What gas is given off in rooms in respiration?

23. Whence do plants obtain their carbon? Can it be produced by plants? What does a seed consist of? What three conditions are necessary to vegetation?

24. What changes does the air undergo in the germination of seeds? How can seeds sprout in water? What gas is favorable to germination? How may carbonic acid be removed from the seed?

25. What element abounds in dried plants? Are plants able to decompose carbonic acid? What use do they make of it?

26. Why, then, does not carbonic acid unduly increase, and oxygen diminish?

27. In what form is water found in air? Of what use is it? Explain the fall of rain. When is mist formed? Under what circumstances is hail formed?

28. What do you know of fogs? Why are London fogs so disagreeable?

29. Why is not water always visibly present in air? Can you prove that it is ever present? How can you explain the phenomenon of dew?

30. Is dew of importance in warm climates? Does it fall equally upon all bodies? Why does no dew fall on cloudy nights?

31. Why does nocturnal radiation injure plants in spring and autumn? How do gardeners prevent it? What plan do the natives of Peru adopt?

32. Is water an element? Who first proved the compound character of water?

33. What is hydrogen obtained from? Whence its name? What are its properties? Does it exist in nature in a free state?

34. Can hydrogen be inhaled in a pure state? Is it poisonous? Then why is it injurious?

35. What is detonating gas? How is it made? Why is it so called?

36. Is ammonia a constituent of air? In what form? Whence its name? What are its chief properties? Is it soluble in water? To what extent? Why do we not smell the ammonia of air? What are the sources of it? How much of it is there in air? What is the use of it? Are salts of ammonia ever found in plants? Can they be taken up by the roots of plants? Why is guano so valuable a manure?

37. What accidental impurities does air contain? In sea-air what do we always find? What acid is formed in thunder-showers?

38. What gas, most injurious to health, is given off from drains and sewers? Name any other sources from whence it proceeds? Can you give any proofs of its fatal character as regards animal life?

39. To what causes may we attribute the rise and spread of contagious diseases?

40. How is it that the air does, on the whole, so evenly maintain its composition?

41. What do we understand by the law of diffusion of gases?

42. What are the effects of this law?

## CHAPTER II.

### THE CHEMISTRY OF COMBUSTION, AND OF THE ARTIFICIAL SOURCES OF LIGHT AND HEAT.

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43. THE fact, that the oxygen of the air plays the part of supporter of combustion, has been already alluded to. Combustion is always accompanied by the phenomenon of heat, and frequently by that of light : indeed, the two tend to produce, and are probably convertible into, each other. It is a popular error to suppose that the rays of the moon form an exception to this rule; it will cease to be matter of wonder, that our best instruments do not indicate any *heat* in them, when we reflect that a single ray of the moonbeam possesses only the 1-300,000th part of the light of a solar ray of the same size.

44. In all ordinary cases of combustion, AIR is present, and all the phenomena of combustion may be explained by the sudden chemical action which ensues at high temperatures between the burning body and the oxygen of the air. Not that any temperature can be fixed at which bodies burn or inflame in air ; on the contrary, some take fire the moment they are exposed to it; others at a tem-

perature a very little above that of summer-heat; some only at a very high temperature; others again refuse to burn under any condition. The products of combustion, the result of the union between the oxygen and the burning body, are usually gaseous, and hence they escape the notice of the ordinary observer. Before, however, we can with any profit, consider these products, we must well understand the nature of those substances which are more or less employed as sources of light and heat.

45. Attention has already been drawn, in some degree, to that fundamental constituent of most sources of flame, CARBON. It is of universal occurrence in the animal and vegetable, and is found largely in the mineral kingdom. Carbon forms also the chief constituent of coal. When combined chemically with oxygen, as CARBONIC ACID, it is met with, in a free state, in the air, and in water; and further, in combination with lime, as carbonate of lime, in limestone and marble; and in not a few minerals besides. A lump of carbon or charcoal undergoes no change on exposure to air, or when buried in the ground; its affinity for oxygen is, therefore, not exhibited at ordinary temperatures. But when heated to redness, combustion takes place, the charcoal burns and disappears, with the exception only of a small quantity of ash.\* The *heat* developed is the result of its union with the oxygen

\* Ash is the incombustible matter of charcoal, of coal, and of plants generally. The combustible matter of coal is called *organic*; the ash is called its *inorganic* constituent.

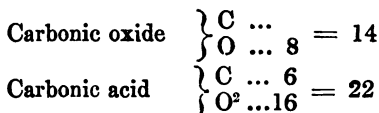
of the air. The gas generated from the lump of charcoal, or, in other words, the gas into which the charcoal is converted, is this very carbonic acid.

46. Carbonic acid, then, is a chemical combination of carbon with oxygen. By whatsoever method prepared, it has always the same composition, for it is a law of nature that chemical combinations always take place according to certain fixed proportions, by measure *and* by weight. This law is the very basis of chemistry, without which the science could have no existence. The relative quantities, too, in which bodies unite, may be expressed by proportional numbers. Thus : 16 parts of oxygen unite with 6 of carbon, to form 22 parts of carbonic acid.

47. Not that carbonic acid is always the result of the union of carbon with oxygen. When coal burns at a temperature below redness, or when carbonic acid passes over hot coal, the carbon unites with less oxygen in the first case, and with more carbon in the second. The result is, the formation of a new compound, CARBONIC OXIDE. It is a colorless gas, of a faint, peculiar odor, and even more poisonous than carbonic acid. It is inflammable ; the blue flame often to be observed in coal fires, arises from the burning carbonic oxide, which unites with more oxygen, and becomes changed into carbonic acid.

48. So far we have considered two combinations of carbon with oxygen. Employing the language of chemists, in expressing the elements by the FIRST letter of their Latin names, carbon may be represented by the capital letter C,—oxygen by an O.

49. 6 parts of carbon unite with 8 parts of oxygen, to form carbonic oxide: but 6 parts of carbon require 16 parts of oxygen to form carbonic acid. The *combining proportions* of these two compounds are as follow :—



50. The *equivalent* (so called, because the combining proportion of one body is, as it were, equivalent to that of another body, and may be substituted for it in combination,) of carbonic oxide is, therefore, expressed by the figure 14; that of carbonic acid by 22.

51. Of the exact nature of the ultimate forms of matter, we can only form an opinion; but most successful attempts have been made to explain the *reason* of the very remarkable manner in which combination occurs, in the production of chemical compounds. It is believed that matter is composed of certain ultimate particles, or molecules (diminutive from *moles*, a mass), which, by their nature, are indivisible, and are hence called **ATOMS**, from *ἄτομος*, (atomos) that which cannot be cut. According to the **ATOMIC THEORY**, every compound is formed of the atoms of its constituents. Thus, to refer to the case just considered, one atom of carbon unites with one atom of oxygen to produce carbonic oxide, and with two of oxygen to form carbonic acid. We may represent such combinations in the following manner :—

Carbonic oxide.

CO

Carbonic acid.

OCO

8 parts by weight of oxygen unite with 6 parts by weight of carbon, to form carbonic oxide: 16 parts of oxygen united with 6 parts of carbon, always form carbonic acid. The atomic theory supposes the ultimate forms of matter, that is to say, each atom of different elements, to possess different weights. The weight of an atom of carbon is, therefore, less than that of an atom of oxygen. The term equivalent is applied to the number 6 (which represents an atom of carbon), because it represents the quantity capable of exactly replacing another in combination: for the same reason, the numbers 6 and 8 respectively represent the combining quantities or proportions of carbon and oxygen.\*

52. One hundred parts of the two compounds of carbon with oxygen consist of:—

Carbonic oxide	}	C ... 42·86	=100·00
		O ... 57·14	
Carbonic acid	}	C ... 27·27	=100·00
		O ... 72·73	

53. And not only are the elements expressed in symbolic language, but also the proportions in which they are united in chemical compounds. Thus, to express the two compounds of carbon with oxygen by a symbol, we write:—

Carbonic acid = CO<sup>2</sup>

Carbonic oxide = CO

which at once indicates the character of the combi-



nation. It shows, that whilst both contain the same amount of carbon, carbonic acid contains twice as much oxygen.

54. But to continue our subject. Next in importance to carbon, as a source of heat, is HYDROGEN. Its symbol is H. In point of specific gravity, it is the lightest form of matter we are acquainted with, an equal volume of common air being fourteen and a half, and of oxygen sixteen, times its weight. Its density, as compared with air, is 0.0691; hence 100 cubic inches will weigh 2.14 grains. Although it is not a supporter of combustion, and is, in the absence of air, an extinguisher of flame, yet, when inflamed in presence of air, it burns with a pale blueish hue, and emits very great heat. The product of the union of hydrogen with oxygen, is pure WATER,—a compound of 8 parts of oxygen and 1 of hydrogen, or of an equivalent of each element.

55. Exact experiments have shown that two measures of hydrogen unite with one of oxygen. In forming water, the three measures or volumes condense into two. An admixture of these two gases in the proportions to form water, when inflamed, is productive of the greatest known amount of heat. This OXY-HYDROGEN flame, as it is called, is capable of fusing the most intractable metals, platinum being softened and melted by it as easily as gold in a furnace.

56. The *flame* of such a light is weak; indeed it is believed that pure gaseous matter is not capable of giving out *light*. Certain it is, that the heat of

a flame is independent of its light, for it is well known that common air may be heated to such an extent, that it will inflame pieces of wood, and yet itself remain invisible. A good instance of this is afforded by the fact, that the air which issues from the chimney-glass of an argand gas-burner, will make a thin piece of wire red-hot, even when held several inches above the flame.



Fig. 8.

57. To carbon and hydrogen, as sources of light and heat, must be added OXYGEN, the symbol of which is O. It may be produced artificially from a variety of sources; but the principal feature of this gas, is the extraordinary brilliancy with which bodies burn in it. Bodies which burn in air, burn with greatly increased splendour in oxygen. Thus, if a taper be blown out, and then introduced into a jar of the gas, (fig. 9) while the wick remains red-hot, it is instantly rekindled: a slip of wood, or a match, treated in the same manner, is relighted. When a piece of charcoal, (affixed to a wire) is plunged with a single point red-hot into a jar of oxygen, it burns with great brilliancy,



Fig. 9.

throwing off beautiful scintillations, until, if the oxygen be in excess, it is completely consumed. Coiled watch-spring, or a piece of spring-wire, heated to redness, and immersed in oxygen, (fig. 10) exhibits a most beautiful appearance of combustion. Phosphorus, when inflamed in air, where the oxygen is mixed with four times its volume of nitrogen, burns with a very bright light; but it is no more to be compared with the brilliancy of phosphorus burning in oxygen, than is the light of the sun to that of the moon. In these, and in other cases which might be mentioned, the same ultimate effect is produced, as in atmospheric air: oxygen being, in fact, the *sustaining principle of combustion*.

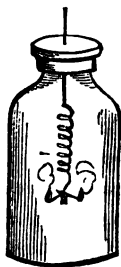


Fig. 10.

58. All the elements are capable of oxydation, and most of them at a temperature more or less high, with the evolution of heat and light.

59. A substance incapable of further entrance into combination with oxygen, such as water and carbonic acid, is called *incombustible* or *uninflamable*.

60. Whenever a body unites with oxygen, it increases in weight by as much as it has absorbed of the gas.

61. The term *destruction* of bodies by combustion, is therefore incorrect, inasmuch as matter is *indestructible*; in fact, when we *seem* to destroy a candle, or a lump of coal, by burning them, we only compel them to enter into new forms of combina-

tion, which being gaseous, are either immediately dissipated in air, or may be detected escaping up the chimney. When the product of combustion happens to be a *solid* body, as in the case of inflamed phosphorus and zinc, we may more readily believe the evidence of our senses, as we can handle and weigh the phosphoric acid and oxide of zinc thus produced.

62. Of the many numerous services which Chemistry has rendered to household economy, there is certainly none which possesses more general importance and interest, and none that has been more fully developed, than that of lighting by means of gas obtained by the destructive distillation\* of coal. Although its application as a means of procuring artificial light is of modern invention, yet the germ of it may be traced back nearly two hundred years. Dr. Robert Clayton, Bishop of Cork and Ossory, first distilled coals in a retort and obtained gas. He says: "I kept this spirit (gas) in the bladders; and, when I had a mind to divert strangers or friends, I have frequently taken one of these bladders, and pricked a hole therein with a pin, and compressing gently the bladder near the flame of a candle till it once took fire, it would then continue flaming till all the spirit was compressed out of the bladder; which was the more surprising, because no one could discern any difference in appearance between these bladders and those which are filled with common air." But the first application of coal-gas to

\* A process by which organic substances are strongly heated in vessels, from which air is excluded.

illumination was made in 1792, by Mr. Murdoch. Novel as was this mode of lighting his own dwelling, it did not attract public attention until the year 1802, when the front of the Soho manufactory of Messrs. Bolton and Watt was lighted by him with a public display of gas-lights, on occasion of the national illumination in the spring of that year, at the peace of Amiens. In 1810, the National Light and Heat Company obtained an act for the purpose of illuminating London streets, and before 1825 every oil-lamp in the public streets was displaced by gas.

63. In COAL, we see the remains of a vegetation which covered the earth before it was inhabited by man. A large portion of the purest kind has been formed by plants which grew on the spot, and somewhat in the manner of peat on the spaces now covered by the beds of coal. The former existence of land in some of these spaces has been proved by the occurrence of numerous upright fossil trees, with their roots terminating downwards in seams of coal. Our coal-mines furnish almost a complete fossil flora; a history of many of the now lost species which once decorated the surface of the earth. There is a great resemblance between the plants of the coal-formation and the flora of New Zealand. The botany of those islands is characterized by abundance of ferns, one hundred and forty species of which are already known, some of them attaining the size of trees. Another point of resemblance is the prevalence of the fir tribe.

64. Deposited at the bottom of seas, lakes, or

rivers, and subsequently covered up by accumulations of clay and sand (since hardened into slate and gritstone) the vegetable matter has undergone decomposition. The pressure of those deep strata of slate and gritstone has not only prevented the evolution of gas, thus giving to the coal the property of burning with flame, but has obliterated most traces of vegetable structure, and given the pit-coal the close and compact quality of stone.

65. The difference in the appearance of the several varieties of coal is not greater than the difference in their composition. The principal constituents of coal are CARBON, HYDROGEN, OXYGEN, and NITROGEN. Of these, carbon, hydrogen, and oxygen, may be considered as the elements of *pure* coal; but common coal always contains a quantity of earthy impurities. The different kinds of coal comport themselves in the fire as ordinary organic\* substances, in which the combustible elements, carbon and hydrogen, are condensed into a small volume. For gas-illumination the value of the coal is proportional to the quantity of volatile matters which it disengages at a red heat. Thus, Mr. Mushet found in—

VOLATILE MATTER.		COKE.	
		Carbon.	Ash.
Derbyshire coal	47·000	48·362	4·638
Scotch cannel coal	56·570	39·430	4·000
Welsh furnace coal	8·500	88·068	3·432

\* Organic substances are derived mainly from the vegetable and animal kingdom, and are the products of vitality. They are usually compounds of carbon, hydrogen, oxygen, and nitrogen, and combustible in air and in oxygen.

66. The composition of *pure* splint and cannel coal, according to Richardson and Regnault, is represented by the formula  $C^{24} H^{13} O$ ; which gives, when explained in proportions per cent. :—

Carbon . . . . .	87·27
Hydrogen . . . . .	7·88
Oxygen . . . . .	4·85
	<hr/>
	100·00

67. Nitrogen does not seem to be an element of pure coal; but as all kinds of coal give, on distillation, a larger or smaller proportion of products containing AMMONIA, we must suppose its existence to be constant. We do not know in what form the nitrogen exists; though given off in combination with hydrogen, as ammonia, when coals are burnt, it certainly does not pre-exist in the latter form.

68. The *ash* of most kinds of coal consists chiefly of such incombustible substances as *sand*, *clay*, *gypsum*, *chalk*, and *iron*. Unfortunately for some applications of coal, especially that of making gas, few varieties are free from *iron-pyrites*. This mineral is generally visible to the naked eye, presenting frequently a gold-like appearance. It contains sulphur, or brimstone. The presence of that most nauseous gas, *sulphuretted hydrogen*, in unpurified coal-gas, is derived entirely from the iron pyrites.

69. The production of *coal-gas*, or *street-gas*, is a trade of great magnitude and importance. The coal is placed in oblong cylinders of cast-iron,

which are ranged in furnaces, to keep them at a red-heat, and all the volatile products are conveyed by a tube in connection with all the cylinders into a condensing vessel, kept cold by immersion in water; here all the condensible vapors, such as *water, tar, ammonia*, and other impurities, are retained. The coal-gas, still more or less impure, from the presence of *carbonic acid* and *sulphuretted hydrogen*, is now passed through a mass of slaked lime moistened with water, in vessels called purifiers. The lime frees the gas of its impurities, with which it combines chemically, but it has no affinity for the gas itself. The latter is sometimes still further purified by passing through diluted sulphuric acid, or a solution of sulphate of iron, which removes the merest traces of ammoniacal gas and sulphuretted hydrogen; it is then transmitted for use into gasometers, whence issue the pipes for the supply of streets, shops, and private houses.

70. The largest quantity of gas obtainable is from the Scotch cannel coal, a ton of which affords nearly 12,000 cubic feet. The various kinds of coal employed throughout the kingdom yield, on an average, 8,000 cubic feet.

71. The substances to which the illuminating power of coal-gas is due, are mixtures of distinct chemical compounds of hydrogen and carbon. They are called *hydro-carbons*.

72. The chief constituent of coal-gas, as regards quantity, is LIGHT CARBONETTED\* HYDROGEN. It

\* Or carburetted.



consists in 100 parts by weight, of 75 of carbon and 25 of hydrogen; proportions which correspond to one atom or equivalent of carbon and two of hydrogen. Its symbol is, therefore,  $\text{CH}^2$ . It is a colorless, tasteless, and nearly inodorous gas. If a burning taper is introduced into a jar of this gas, it is extinguished; but the gas itself burns with a *pale yellow flame*, when kindled in the air. The mixture of air or oxygen with this gas, explodes violently by contact with flame. For complete combustion it requires twice its bulk of oxygen, and yields water and its own volume of carbonic acid.

73. Light carbonetted hydrogen is the main constituent of *Will-o'-the-Wisp*. The latter is probably kindled by the presence, in minute quantities, of spontaneously inflammable phosphuretted hydrogen—a gas the product of the putrefaction of certain parts of vegetables and animals.

74. When the mud at the bottom of pools, in which plants grow, is stirred, bubbles of gas escape, which, on being collected and examined, prove to consist chiefly of light carbonetted hydrogen; on which account it is also called *Marsh-gas*.

75. Although, as regards quantity, light carbonetted hydrogen forms the bulk of street gas, yet must OLEFIANT GAS, OR HEAVY CARBONETTED HYDROGEN, be considered its most important constituent. It obtained its one name from its property of forming an *oil-like* compound with chlorine; its other, on account of its weight, as compared with light carbonetted hydrogen. The specific gravity

of the two gases, compared with air, is as follows:—

Air . . . . .	1000·
Olefiant gas . . . . .	986·
Light carbonetted hydrogen	559·

It is a colorless and tasteless gas, of ether-like odor. It consists, by weight, of 85·71 of carbon, and 14·29 of hydrogen; otherwise, of two volumes of carbon vapor and two volumes of hydrogen *condensed into one volume*. The peculiar luminosity of its flame is accounted for by its extraordinary condensation. Its symbol is  $C^2 H^2$ . In contact with air it burns with a remarkably white flame, producing water and carbonic acid, from the combustion of its hydrogen and carbon.

76. Besides these two hydro-carbons, there are others present in minute quantities, which communicate to coal-gas its peculiar odor. Carbonic oxide, hydrogen, and nitrogen, are also present; sometimes to a very considerable extent. One hundred volumes of very good coal-gas contain as much as thirteen volumes of olefiant, and eighty-two volumes of light carbonetted hydrogen gas.

77. The whiteness of the flame of coal-gas is then due to olefiant gas; accordingly as this increases or decreases, is the beauty or pallor of the flame. What is it, it may be asked, which renders olefiant gas so valuable as a source of light?

78. It has been already mentioned that pure gaseous matter is incapable of giving out light. No flame possesses so little light as that of oxy-hydro-

gen, none such intense heat. But the luminosity of flame does not depend so much on its temperature, as on the presence of solid matter diffused through the flame and ignited by it.

79. It is true this cannot always be seen, but it is nevertheless present. Let us examine into the case before us. When coal-gas burns, no solid matter can be seen in its flame; but if you depress a white saucer into the flame, you find it immediately covered with *solid* carbon, or soot, and the light impaired. **THIS CARBON IN A STATE OF WHITE HEAT IS THE CAUSE OF THE LUMINOSITY OF ALL ORDINARY FLAMES.** In an ordinary gas-flame, the gas is in free contact with the air only near the bottom, and on the very outside of the flame. Perfect combustion, therefore, only takes place at those parts. In the interior or brilliant part of the flame, the air supplied is insufficient, and the heat so great, as to separate the coal-gas into its constituents, hydrogen and carbon. The hydrogen burns (forming water), while the carbon is deposited in a state of white heat, and is only converted into carbonic acid on the exterior of the flame. That flame requires a high temperature for its existence, is proved by the fact that any cold substance depressed upon it removes a portion of its carbon. The great condition that must be complied with in order to obtain a bright light from *gas*, is to take care that it has a constant supply of fresh air. This is accomplished by two methods. By the first, the gas is made to stream out in thin apertures, surrounded both internally and externally by air, as

we see in the common Argand burner, (fig. 11) ; by the second (see fig. 8, p. 41), not only is the gas protected externally by the chimney-glass from any sudden gusts of cold air, but the brightness of the flame is greatly increased by a continued stream of air, which rushes in regularly from below the glass, exactly in the same proportion as the heated air streams out from above. In proportion as the draught is increased, will the flame be brighter. Its hydrogen and carbon must be burnt completely: when the combustion of carbon is incomplete, not only does the flame smoke, but much light is lost.

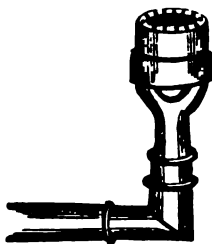


Fig. 11.

80. The increase of light is, of course, far greater in the case of an Argand burner, if, in the place of air, oxygen is passed up the internal opening. The *Bude Light* of Mr. Gurney was originally so constructed. But the light now known as such, is nothing more than an ordinary gas-flame, from three, or more, large concentric Argand burners, with chimneys and reflecting apparatus.

81. To obtain a full amount of light from any burner, the flame should always be made as large as possible without smoking.

82. Of the economy of gas, as compared with all other sources of light, no doubt exists. But wherever it is used, more than ordinary attention should be paid to ventilation. When we consider

that one part by weight of coal-gas produces two and a half by weight of poisonous carbonic acid, the importance of this observation will be readily admitted. Head-aches are the least penalty paid for the neglect of this precaution.

83. It may tend to give some idea of the extent to which gas is manufactured, to notice, that London alone consumes 3,000,000,000 cubic feet, equal to from 50,000 to 60,000 tons weight.

84. Whilst yet on the subject of coal-gas, another property of flame must be mentioned. The inflammable gas which escapes from fissures in coals, the so-called FIRE-DAMP of miners, has almost the same composition as coal-gas. When it accumulates so as to form 1-7th of the atmosphere in a coal-mine, the approach of flame instantly causes a tremendous explosion, and the poor miner is either burned to death, or choked by the carbonic acid (choke-damp) formed in its combustion. To remedy this, Sir H. Davy undertook many experiments, which at last led to the construction of that most ingenious instrument, the miner's *safety-lamp*. Its efficacy depends upon the fact, that flame, requiring a high temperature for its existence, is extinguished at a temperature below redness. To illustrate this, take a piece of wire-gauze, (of such fineness as to have about 800 apertures to the square inch), and depress it quickly upon the burning gas-jet; you

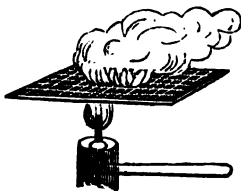


Fig. 12.

will find that the flame will be cut off (fig. 12) just where it touches the gauze. The inflammable matter of the flame (much of the undecomposed gas, together with a good deal of soot) passes through the gauze. In its passage it is so far cooled as to be extinguished; the *flame*, therefore, is prevented from passing, although the gas is not. If you bring a piece of lighted paper above the flame, to the upper side of the gauze, the gas will be rekindled, and burn as before. Again, by varying the experiment, and turning on an unlighted jet of gas underneath the gauze, you may kindle the flame above, and it will not pass through. The cooling property of the wire-gauze is owing to its great power of conducting heat. Sir H. Davy, who is the author of these and many other experiments on flame, placed a lighted lamp within a perfect cylinder of wire-gauze, (fig. 13) and found that although inflammable gases would pass through and could be enkindled, yet the flame would not be communicated to the air without; hence its value in mines, where combustible gases are of frequent occurrence. The safety of these lamps depends of course entirely upon the perfect state of the wire-gauze, and upon other circumstances too numerous to mention. For, after all, real safety is only then guaranteed to the poor miner, when his place of work is completely ventilated.



Fig. 13.

85. Combustible as most kinds of coal are, they must be heated to a certain extent before they will

in flame. This is accomplished by the use of the more readily combustible paper and wood. They are laid in the grate, and the coal is heaped upon them in such a manner, that the air may have free access. When the coal is heated below redness, its hydrogen unites partly with its own oxygen, partly with that of the air, and escapes up the chimney in the form of steam. The heat at first is usually insufficient, and therefore a quantity of the carbon of the coal is separated from the hydrogen, which ascends up the chimney as smoke. At length, after the heat has been somewhat increased, the olefiant and other gases burst out into a flame, which continues as long as the supply of the hydrogen lasts. As long as any carbon is left, the coals retain their glow, and continue to burn, though no longer with flame, until nothing remains in the grate but the incombustible ashes.

86. And now, with reference to the actual combustion of the fuel ; we know that this is due to its union with oxygen. In the combustion of coal, carbonic acid, and watery vapor, are mainly formed ; together with small quantities of sulphurous acid and ammonia. Of the properties of carbonic acid, of its power of extinguishing flame, and its heavy character, notice has been taken. Its weight, indeed, would very seriously interfere with the burning of the coal, were it not for the important fact that the heat evolved by the combustion itself, is the very agent by which it is carried off as fast as it is produced. When this, or any other gas, is heated, its particles expand ; its actual weight remains un-

changed, but it occupies a larger space. Thus, when a portion of air is heated in the open atmosphere, it expands and rises upwards, not because it has, of itself, any tendency to rise, but because the heavier cold air around is displaced. A flame ascends simply because the heat given out by it expands the surrounding air, and makes it lighter than air usually is. The heat evolved not only ensures the removal of the carbonic acid, but also causes a circulation of fresh air through the burning fuel. In a good grate, therefore, all these gases are carried off up the chimney, upon the *draught* of which the burning of the fire greatly depends. A fire, therefore, serves the purposes both of ventilation and heat. When the weather is cold, we make a large fire, and thus, of course, expand a larger volume of air than usual, in consequence of which a larger amount of cold air will rush into the room. The ascent of smoke then being dependent upon the admission of colder air, the fire will only burn well, and the chimney draw, accordingly as we allow it to enter.

87. The waste of fuel, which takes place when much of it is allowed to escape in the form of smoke, arises mainly from insufficient access of air, and might be prevented by judicious management. The very common practice of heaping up a fire with fresh coal, when it has burnt very low, is clearly objectionable, because the chilling of the fire thus occasioned, evaporates the fuel in the form of smoke, without burning it. A good fire, without waste, is



most readily obtained by the frequent application of coal in small quantities.

88. As to the temperature of a fire, a dull red heat, visible in daylight, is probably equal to  $1,000^{\circ}$ , a full red-heat, to  $1,200^{\circ}$ , an orange-heat to  $1,700^{\circ}$ , and a white-heat to  $3,000^{\circ}$ . The latter is never attainable in a common fireplace.

89. LIGNITE or BROWN COAL, which is used as fuel in some parts of the world, rarely occurs in extensive fields, as does pit-coal. It has usually a brown color, burns with a dark smoky flame and a very disagreeable odor; it consists, in fact, of vegetable matter but little altered.

90. ANTHRACITE (from *ανθρακος*, anthrakos, black) belongs to the same formations as pit-coal. It is of a jet-black color, and very lustrous: it contains sometimes as much as 94 per cent. of carbon, inflames with difficulty, but gives much heat in combustion.

91. PEAT and TURF consist chiefly of the remains of plants which have undergone comparatively little change.

92. WOOD may be said to contain, on an average, nearly equal weights of carbon and the elements of water. From this it may be inferred, that wood fires will not only burn with much flame and little smoke, but will give out intense heat, and consume very fast. There is also a very peculiar odor which usually accompanies the burning of wood. Among the products of the destructive distillation of wood (which differ in many respects from those of coal),

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are *wood-naphtha*, *vinegar*, and *creasote*, and it may, therefore, be expected that the vapors of the burning wood will, according to the low or high temperature of the fire, partake more or less of the odor of these.

93. COMMON CHARCOAL, sometimes used as fuel, is usually made of oak, chestnut, elm, beech, or ash-wood. Young wood fortunately affords better charcoal than the finest timber. The billets are formed into a conical pile, which, being covered with earth or clay, is suffered to burn with only a limited access of air. The oxygen and the hydrogen of the wood combine to form water, and but little of the carbon is consumed. Charcoal contains about 2 per cent. of certain salts, which, after combustion, remain in the form of ash; but the quantity and quality vary according to the nature of the wood.

94. The chemistry of the candle properly succeeds to the foregoing considerations of gas and fuel, as sources of light and heat.

95. The best candles are made of WAX, a substance collected by bees, in small quantities, from the pollen and other parts of flowers, but produced chiefly by those insects from the sugar contained in the nectaries of every flower. When fresh from the honeycomb, it is of a yellow color, and possessed of a peculiar smell: drawn out in thin layers, the effect of sunlight upon wax is to deprive it of both smell and color. By the action of hot alcohol, wax may be separated into two distinct substances, CERIN and MYRICIN. Cerin constitutes the largest portion of bees-wax, and has the same composition as

myricin. Both are compounds of carbon, oxygen, and hydrogen, in such proportions as the formula of cerin will best indicate:  $C^{68} H^{60} O^4$ .

96. SPERMACETI is found in certain hollows in the head of the various species of Delphinus; but more especially in the spermaceti-whale, *Physeter macrocephalus*. During the life of the fish it is dissolved in spermaceti oil, but at death it separates in hard crystalline masses. Freed entirely from the oil, it may be said to consist of CETIN, a crystalline substance of pearly lustre. It is a fat, of which the formula is  $C^{64} H^{66} O^4$ .

97. TALLOW is the fat of oxen and sheep melted and freed from its natural impurities. The inferior tallows have a yellow tinge; but when pure they are white and tasteless. The best tallow is used for candles; inferior for soap. About 70,000 tons are annually imported from Russia and Australia, besides the quantity supplied by the home market.

98. The chief ingredient in tallow is STEARIN, or STEARATE OF GLYCERIN. Stearin, so named from *stear* (stear), tallow, is quite insoluble in water, but soluble in hot alcohol and in ether. It is much employed, when mixed with one-fourth of its weight of wax, in making *composite*, or *stearin* candles. When properly made, they are white and inodorous, and burn with as white a flame as wax, though a little more rapidly.

99. The name stearate of glycerin gives a more exact insight into the character of the chief constituent of tallow than does stearin: it is a compound of STEARIC ACID with GLYCERIN. Stearic

acid is a white crystalline solid, represented by the formula  $C^{68} H^{66} O^6$ .

100. Glycerin differs materially from it. It is a syrupy liquid, rather heavier than water, in which it may be dissolved to any extent. It has a sickly sweet taste, which gave occasion to the name, from *γλυκύς* (glukus), sweet. It burns with a bright flame. Its formula is  $C^4 H^8 O^6, 2HO$ .

101. MARGARIN, or MARGARATE OF GLYCERIN, is also to some extent a constituent of tallow. It forms the chief constituent of human fat and goose fat, and is contained in most fats and oils. It is solid at common temperatures, but less hard than stearin.

102. The only acid peculiar to margarin, MARGARIC ACID, from *μαργαρίτης*, (margaritees) a pearl, on account of its pearly lustre, greatly resembles stearic acid. Its formula is  $C^{68} H^{66} O^6, 2HO$ .

103. OLEIN, or OLEATE OF GLYCERIN, we also find in tallow, but to a very small extent as compared with the liquid fats or oils.

104. OLEIC ACID is an oily liquid, of a slightly yellowish tint. It reddens blue litmus paper, has a weak odor and a pungent taste. It is soluble in alcohol and in ether. Its formula is  $C^{36} H^{38} O^3, HO$ .

105. COCOA-OIL, extracted by pressure from the steamed nuts of the *Cocos nucifera*, a species of palm-tree, is a white fat of the consistence of lard. It contains olein and a solid hard fat, resembling stearin, which is often used as a substitute for tallow in making candles.

106. It would appear from what has been already

stated, that the consistence of oils and fats must be related to the proportion, in the oil or fat, of olein on the one hand, and of stearin and margarin on the other. Where stearin predominates, the fat is very firm. If margarin abounds, it is soft like lard ; if olein, it is liquid.

107. It is unnecessary to enter into the mechanical process of making candles, beyond stating that mould candles are made by casting melted tallow into metallic cylinders with the wick in the centre.

108. All the materials enumerated above, inflame of themselves at a high temperature, in air, and burn with a very bright flame. But the temperature which renders them gaseous, decomposes them, and they emit a suffocating odor. It must therefore be evident that they could not subserve the purpose of lighting a room, unless by some contrivance the melted materials should undergo complete combustion.

109. Fortunately they all *melt* at a comparatively low temperature, and comport themselves as liquids, and by the use of *wicks* we can accomplish the combustion of a candle without smell. These are usually made of twisted cotton, the separate threads of which act as narrow tubes, and draw up the oil or melted tallow by what is called *capillary attraction*.\*

\* A variety of adhesion, which exhibits itself in the rise of fluids up tubes of a very narrow bore, to a height far above that of the level of the liquid in which the tubes are placed. The term capillary is derived from capillus, a hair, because the more the tubes resemble hairs in the fineness of their bore, the higher will be the ascent of the liquid.

In composition, these wicks partake much of the character of dry wood: for complete combustion they require a larger amount of oxygen than they ordinarily obtain, and therefore need *snuffing*, because the whole of the carbon cannot be consumed.

110. In order to supersede the necessity for snuffers, wicks are now prepared, in which either a thin metallic wire is interwoven, or which are steeped in solutions of nitrate of bismuth or lead, salts containing large quantities of oxygen, which, at the high temperature of the ignited wick, oxydises and consumes it. In Palmer's candles the wick is formed of two halves twisted spirally round each other. Each half is bound round in a tolerably compact form, and the process of untwisting the spiral by the gradual burning of the candle causes the tops of the two wicks to spread out laterally beyond the limits of the flame. The charred part of the wick coming into contact with air, oxydizes, and is changed into carbonic acid gas.

111. Wicks are sometimes made of asbestos, for use in oil-lamps, a mineral substance unchangeable in fire. Even glass tubes are occasionally used as substitutes for cotton wicks in night-lights.

112. Before further considering the flame of a candle, it will be as well to clear the way of every difficulty. All the sources of light so recently enumerated consist only of carbon, hydrogen, and oxygen, in certain fixed proportions. The affinity of the hydrogen for the oxygen is greater than that of the carbon. The gases which are obtained from the tallow or wax, in passing through the-inflamed

wick, are very similar to coal-gas. They are mixtures of olefiant gas with light carbonetted hydrogen, and in speaking of them we shall simply call them *gas*.

113. The light of the flames of tallow, wax, and oil, is due to the same cause as that of coal-gas. The formation of gas may be thus described: the melted tallow, or wax, or the oil, drawn by capillary attraction into the burning wick, is there decomposed and converted into gas, which rises in a conical form, and is of a temperature sufficiently high to unite with the oxygen of the air. But this combustion is superficial only, as the flame includes a portion of heated vapor which cannot burn for want of oxygen. If the structure of the flame be examined yet a little more minutely, it is seen to consist of three distinct parts. The *dark* centre represents the unburnt combustible cone of gas. The *brilliant* part of the flame, or that which gives out light, surrounds the dark cone; in this the gas is decomposed, the hydrogen alone burns, while the carbon is deposited in minute particles, which become heated to whiteness. And then, again, on the very *exterior* is another portion, scarcely visible, in which the carbon burns. The combustion of the hydrogen produces the heat of the candle, and the particles of carbon radiate the light. The heat in the centre of the flame is so low, that gunpowder may be held there without becoming ignited. The hottest part of the flame is just at the top of the



Fig. 14.

luminous cone, where the combustion is perfect.

114. The chemical effects produced on many substances by the exterior and interior parts of the flame, are exactly opposite. Just within the luminous cone, most compounds of oxygen are *deprived* of their oxygen, *de-oxydized*, or *reduced*; but at the summit of the flame, metals are *oxydized*. If a piece of copper wire is held at the very point of the flame, it rapidly becomes covered with a coating of oxide of copper; but, on depressing the wire into the interior of the flame, the oxide is *reduced* (as it is called, from *reducere*, to lead back again), and the wire again becomes bright.

115. When the combustion of a tallow or wax candle is complete, nothing but carbonic acid and water is given out to the air. *There is no smell*. But if a lighted candle or lamp be carried quickly through the air, it smokes and gives out an unpleasant smell, because the temperature of the flame is so much lowered, that it can no longer consume all the carbon, or all the vapor, of the decomposed tallow, wax, or oil.

116. CAMPHINE,  $C^{20}H^{16}$ , or rectified oil of turpentine, is a clear, colorless liquid. The amount of carbon in it, as compared with its hydrogen, is so great, that no ordinary wick would effect its combustion. But by the application of the principle of the Argand-burner, and the use of a chimney-glass, tinged of a pale blue, sufficient air can be supplied to the circular wick, to cause the production of the most brilliant and most perfect artificial light for ordinary purposes with which we are acquainted.



117. Not that such a light is perfect ; far from it. All artificial lights are faulty, when compared with sun-light.

118. The proportion in which the primary colors combine to form white or day-light is:—

Yellow ... 3 parts

Red ... 5 parts

Blue ... 8 parts

119. If these proportions are not maintained, the light, instead of being white, will be tinged with whatever hue is in excess. All our ordinary lights abound in yellow and red rays, for it requires a high temperature indeed to produce the blue rays in abundance.

120. To the discomfort occasioned to the eye by the excess of the yellow or red rays, must be added, the heat of flames, and their unsteadiness.

121. The injurious effects of artificial light may be much lessened by surrounding the light with a shade, colored blue on the inner surface, or by a lamp-glass similarly tinged, which tend to absorb the excess of yellow and red rays.

43. What is the chief object of oxygen? What phenomena always accompany combustion? Are heat and light convertible into one another? Does moonlight form any exception?

44. What is necessary to all ordinary combustion? Can the temperature be fixed at which bodies burn in air? Why do the products of combustion usually escape notice?

45. What is the fundamental constituent of most sources of artificial heat and light? Is it of abundant occurrence? Name some of the sources? When it unites with oxygen what acid is formed? Does it exist in a free state? Where? To what extent? Do we find it in combination? What are its salts called? Does carbon buried in the ground or exposed to air undergo change? But when heated, what becomes of it? What is ash? Which is the organic part of coal? What is the occasion of the heat produced in burning carbon?

46. Has carbonic acid always the same composition? Does combination always take place in fixed proportions? In what proportions do carbon and oxygen unite to form carbonic acid?

47. Is there no other combination of carbon with oxygen? What is its name? When is it formed? What are its properties? Have you ever seen it burn?

48. How may the elements carbon and hydrogen be expressed symbolically? How do chemists briefly express the names of elements?

49. In what proportions are the elements combined, in forming carbonic acid and carbonic oxide?

50. What do we understand by equivalent? Can you give the equivalents of carbonic acid and carbonic oxide?

51. Have we any notion of the nature of the ultimate forms of matter? Can any good reason be given for the manner in which combination takes place? What do we understand by atoms? What is the derivation of the word? What then is a compound made of? How may the combinations of carbon be expressed? How much less in weight is an atom of carbon than one of oxygen? What are their respective weights?

52. How much carbon and oxygen are contained in 100 parts of carbonic acid? How much in 100 parts of carbonic oxide?

53. How do we express the formulæ of carbonic acid and oxide? How much more oxygen does carbonic acid contain?

54. Is hydrogen a source of heat? What is its symbol? What compound does H form with O? How much lighter than O and air is H? What is water a compound of?

55. What is oxy-hydrogen? What is most characteristic of the mixture?

56. What kind of flame, as regards brightness, is that of oxy-hydrogen? Is pure gaseous matter capable of giving out light? Give an instance?

57. Is there any other source of light and heat in addition to carbon and hydrogen? In what gas do bodies burn most brilliantly? Give some instances of combustion in O? What may oxygen be called as regards combustion?

58. Are all elements capable of oxidation? With evolution of what?

59. When a substance cannot further enter into combination with oxygen, what is it said to be?

60. Does a body increase in weight by combination with oxygen? To what extent?

61. Is the term destructibility of matter correct? When a candle or coal burns away, what becomes of it? Can you give an instance in which the product of combustion is visible?

62. Who is the supposed discoverer of coal gas? How far back may the germ of the invention be traced? Can you relate an experiment made by Dr. Clayton? What do we understand by the term destructive distillation? Who made the first application of coal gas to illumination? When did lighting by gas become general in London?

63. What is coal formed from? Are traces of vegetation ever met with in coal? To what extent?

64. What changes has the vegetable matter undergone in forming coal? What is the cause of the stone-like qualities of coal?

65. Does coal differ much in appearance and composition? What are the principal constituents of coal? Does pure coal contain nitrogen? How does coal comport itself in fire? Upon

what does the value of coal depend, as regards its illuminating properties? How much ash does coke contain?

66. What elements does splint coal consist of?

67. Is nitrogen found in most kinds of coal? What compound of nitrogen is formed in the combustion of coal? Do we know in what form the nitrogen exists?

68. What is the ash of coal composed of? Of what is iron pyrites composed? What appearance does it present? From whence is the sulphuretted hydrogen of unpurified coal gas derived?

69. Give a brief description of the manufacture of coal gas? Name the various impurities of gas?

70. How much gas is obtainable from a ton of Scotch cannel coal? What may be considered a fair average?

71. What are the light-giving principles of coal gas called?

72. What gas forms the bulk of street gas? What is it composed of? What is its symbol? Its properties? How much oxygen does it require for complete combustion?

73. Of what gas is light carbonetted hydrogen a chief component? How does Will-o'-the-wisp enkindle itself?

74. Why is it called marsh gas?

75. What is the chief compound of gas, as regards quality? Whence the names? What is its specific gravity? What are its properties? What is it composed of? Why does it burn with so great light? What does it form in combustion?

76. Are any other gases contained in coal gas? What percentage of its two chief constituents do we find in every good kind of gas?

77. Upon what, in coal gas, does its luminosity depend?

78. State the chief properties of oxy-hydrogen?

79. Upon what then does luminosity depend? Can you prove it? What element causes luminosity? State the nature of the change which coal gas undergoes in combustion? How do we obtain the brightest light from gas? What element must be completely burnt?

80. What is the Bude light?

81. How do we obtain a full amount of light?

82. Is gas an economical source of light? What is necessary to provide against in its combustion?

83. How much gas is burnt in London?

84. What is the nature of fire-damp? Upon what does the efficacy of the Davy-lamp depend? Illustrate its action. Why does gauze cool down flame? Upon what does the safety of the lamp depend?

85. What is necessary in the combustion of coal? Explain the combustion of coal in a fire-place.

86. To what is the burning of fuel due? Why does not the formation of so much carbonic acid put out the fire? Why does it ascend? Why does flame ascend? Does a fire ventilate a room? How?

87. Could the waste of fuel in form of smoke be prevented? What occasions the chief formation of smoke?

88. What is the temperature of a full red-heat?

89. What is lignite? For what is it used?

90. What is the word anthracite derived from? What are its chief properties?

91. How are peat and turf formed?

92. Of what is wood composed? Why does wood burn away quickly? What are the products of the dry distillation of wood? Do wood fires give out any peculiar odors?

93. What is charcoal? How is it made? What amount of ash does charcoal contain?

94. Why does the chemistry of a candle form a right matter for consideration?

95. How is wax obtained? Of what nature is it? Of what two compounds is it composed? Do they differ in composition?

96. Whence is spermaceti obtained? What is its nature? Of what is it composed?

97. Whence is tallow obtained? What color is it? What is the best tallow used for? Inferior?

98. What is stearin? What other name has it? What are its properties? How are composite candles made?

99. What are the properties of stearic acid?

100. What is glycerin? Whence its name? What are its properties?

101. Is margarin a compound of tallow? Is it contained in other combinations? What are its properties?

102. Whence does margarinic acid derive its name? Of what is it composed?

103. What does olein most abound in? What is its more complete name?

104. What are the properties of oleic acid? Its formula?

105. Whence is cocoa-oil derived? What are its properties? Is it much used?

106. Upon what does the consistence of oils and fat depend?

107. How are mould candles made?

108. At what temperature do wax, &c., inflame? What changes do they undergo in combustion?

109. How can we accomplish the combustion of tallow without smell? Explain the character of capillary attraction? What are wicks made of? Why do they need snuffing?

110. Can snuffing be superseded? How? In what manner are Palmer's candles made?

111. Of what other materials are wicks sometimes made?

112. What elements are all candle materials composed of? Which element burns first? Why? Of what nature is tallow gas?

113. To what cause is the light of candle-flames due? How does the formation of gas proceed? Does combustion take place throughout the flame? Into how many parts may the flame be divided? Explain the different parts. In a candle flame, which element produces mainly heat, and which light?

114. What is the difference between the oxydizing and deoxydizing part of the flame? What changes does copper wire undergo in the two parts? What do we mean by reduction?

115. What compounds are produced in complete combustion?

116. What is camphine? What element abounds in it? What arrangement is required for its complete combustion? Is its light good?

117. Is any artificial light equal to sunlight?

118. In what proportions are the primary colors mixed in sunlight?

119. What colors abound in all common lights? Why?

120. What discomfort does artificial light produce?

121. Can this discomfort be lessened? How?

## CHAPTER III.

### CHEMISTRY OF THE BREAKFAST-TABLE.

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122. In speaking of the various substances which appear on our breakfast-tables, I propose to confine myself to **WATER**, and the various decoctions which are made with it; **SUGAR**, which sweetens our **TEA**, **COFFEE**, and **CHOCOLATE**; **MILK**, which makes it more nourishing and palatable, with its products, **BUTTER**, and (incidentally) **CHEESE**; **FLOUR**, from which our bread is made, and **EGGS**, which form so agreeable and nutritious an addition to our morning meal. **MEAT**, **PRESERVES**, and other accessories at our breakfasts, must be reserved for the Chemistry of another meal, which will hereafter occupy our attention.

123. We shall proceed at once to a further consideration of that fluid, on which depends so much of the comfort of our morning repast—**WATER**. How marvellously useful, and correspondingly abundant, is water! The sea covers nearly three-fourths of the earth's surface; in the form of brooks and rivers water flows through the land in almost every direction; it rises at all times as vapor into the air, forms

clouds, and again descends to the earth in rain or dew.

124. Water is a definite compound of 1 eq. (short for equivalent) of hydrogen, with 1 eq. of oxygen. Symbol HO. Eq. 9. The per centage composition of water is :—

Hydrogen H . . . . 11·11

Oxygen O . . . . 88·89

It is the unit by which the density of solids and liquids is compared, and therefore its sp. gr. (short for specific gravity) is 1.

125. It admits of easy proof, that water is not an element. If we pass steam from a glass retort (*a*) containing water over iron filings heated to redness in

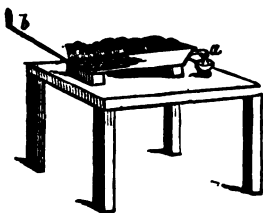


Fig. 15.

a gun barrel, a gas escapes (hydrogen), which burns with flame (*b*), and the iron-filings are found to be rusted or oxydized.

126. Water freezes at a temperature of 32° F. Ice is lighter than water. The sp. gr. of water being

1, that of ice is 0·92.

127. The property of nearly all liquids, except water, is to contract as they cool. However unimportant this exception may at first appear, our admiration must be greater when we reflect upon its consequences. Were it not for this, the very climate of our country would be changed. We know the freezing of water to be due to the coldness of the air; consequently, the upper part of the water is



colder and heavier, and sinks to the bottom. If the water became continually denser, to its freezing point, the circulation of the heavier water to the bottom, and the lighter to the top, would continue till the whole mass of water had reached the ice point; a cold day would then suffice to turn all the water of our rivers and lakes into ice. This does not happen, because water, at a temperature below 40° F., expands, becomes lighter, and floats. Thus freezing can only take place at the surface, and ice be but gradually formed. At a small depth below the ice, water retains the temperature of 40°. Water is most dense at 39·2°. It is slightly compressible, but only under very great pressure.

128. Another striking property of water is its solvent power. Very many solid substances are capable of uniting perfectly with it. Thus, when sugar is put into water, it dissolves, and a solution of sugar is obtained. Whenever solution takes place, the water possesses the taste of the substance dissolved. Thus, the solution of sugar is sweet; and if the water be evaporated\* by heat, the solid substance may be always recovered. Owing to this solvent power, water, as it passes through the earth, takes up many solid substances which more or less injure its purity. The distinction between *soft* and *hard* water, has reference to its greater or less degree of purity; river water is softer than spring water; spring water than sea water. The most

\* Many liquids fly off in vapor or evaporate at the ordinary temperature of the air. Thus, water exposed to the air, disappears more or less slowly, according to temperature.

abundant of all the substances extracted by water from the earth is common salt; hence, we find it in springs and rivers, as well as in the sea. There are, of course, different degrees of saltiness even in the sea. Owing to the great heat, the water at the equator contains more salt than the English Channel, because only the water evaporates; although evaporation is going on constantly all over the ocean. The presence of salt in the sea renders it more buoyant than common water.

129. But the hardness of the water is more especially due to salts of lime. When much gypsum is contained in water, it is deposited by evaporation in kettles and pans, and is said to *scale* them. When, however, the lime is contained in form of carbonate of lime or chalk, this is also deposited at the boiling point, and is said to *fur* them.

130. Gases are also taken up by water. Thus, of the gases already described, one volume of water may absorb—

	Volumes of Gas.
Of ammonia . . . . .	670-000
Of nitrogen . . . . .	0-025
Of hydrogen . . . . .	0-020
Of oxygen . . . . .	0-037
Of carbonic acid . . . .	1-000
Of carbonic oxide . . . .	0-015

Rain, therefore, in passing through the air, absorbs (from *absorbeo*, I suck up) some of its constituents. If rain water be heated, the air will be seen to escape from it in bubbles. Here, again, is seen the importance of this solvent power, it being alone by the

vital air or oxygen thus absorbed, that fishes are able to live in that medium.

131. If water be exposed to heat in open vessels, it boils, and is converted into steam, at a temperature of  $212^{\circ}$  F. If the heat be continued, the whole of the water will evaporate, leaving all solid impurities at the bottom of the vessel. When the process of evaporation is so conducted, that the vapor

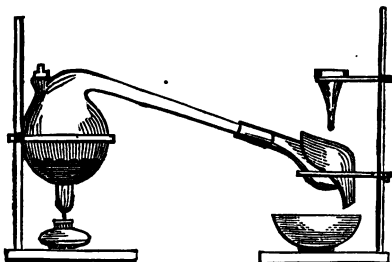


Fig. 16.

obtained from water, heated in a retort (fig. 16), is cooled down, or condensed drop by drop, we obtain *pure distilled water*.

132. It is necessary to point out a distinction which will be of great importance to bear in mind. Most vegetable and animal substances contain a large amount of actual water: but they likewise frequently contain many other compounds, in which oxygen and hydrogen are united *in the proportions* in which they are found in water. Not that these compounds *contain* water, but they can be compelled *to form* water, by destroying their organization! When, therefore, a compound is spoken of as con-

taining the elements of water, the meaning of the expression will be intelligible.

133. The purer or softer the water, the better it is adapted for making infusions of tea and coffee, or decoctions of cocoa. Should, however, water be particularly hard, a little carbonate of soda added to it, will, by removing the lime from solution, much improve it. For the preparation of a good cup of tea, coffee, or cocoa, it is absolutely essential that the water boil.

134. As regards TEA, the cultivation of the tea-shrub, although confined until very lately to the eastern parts of Asia, is carried on over a large tract of country. It grows plentifully in Japan, both in a wild and cultivated state, and is found also in Cochin-China. The plant in cultivation about Canton is known to botanists as the *Thea bohea*, while the more northern variety, found in the green-tea country, has been called *Thea viridis*. Both black and green teas can be made from either, at the pleasure of the manufacturer, and according to demand. There are, of course, still further varieties of tea-plants; for, as the tea-plant is multiplied by seed, like our hawthorns, it is impossible that the produce can be identical in every respect with the parent. The seeds are sown in some corner of the tea-farm, from which they are afterwards transplanted. When about a year old they are planted in rows, five or six together, and about four feet apart. The young plantations are always made in spring, and are well watered by the rains which fall at the change of the monsoon in April

and May. When seen at a distance, a tea plantation looks like a little shrubbery of evergreens; the leaves are of a rich dark green, and afford a pleasing contrast to the strange and often barren scenery which is everywhere around.

135. The young plantations are allowed to grow unmolested for two or three years, the natives being aware that the practice of plucking the leaves is very prejudicial to the health of the shrubs. The length of time which a plantation will remain in full bearing depends, of course, on a variety of circumstances; but, with the most careful treatment, consistent with profit, the plants will not do much good after they are ten or twelve years old; they are often dug up, and the space replanted before that time.

136. The difference in the manipulation of green and black teas may be given in a few lines.

137. *Green Tea*.—The fresh leaves are spread out thinly on flat bamboo trays for the course of an hour or more, in order to drive off all superfluous moisture. In the mean time the roasting-pans have been heated with a brisk wood-fire. A portion of leaves are now thrown into each pan and rapidly moved about, and shaken up with both hands. They are immediately affected by the heat, begin to make a crackling noise, and become quite moist and flaccid, while at the same time they give out a considerable portion of vapor. They remain in this state for four or five minutes; they are then rawn quickly out, rolled up in balls, greatly compressed to get rid of moisture, and then again thrown into the pan. Here the leaves are kept in

rapid motion by the hands of the workmen. In about an hour or more they have become well dried, and their color, *which naturally is of a dullish green*, permanently fixed.

138. *Black Tea*.—With reference to the leaves which are to be converted into black tea—1st, they are allowed to lie for some time spread out in the factory after being gathered, and before they are roasted; 2ndly, they are tossed about until they become soft and flaccid, and then left in heaps; 3rdly, after being roasted for a few minutes and rolled, they are exposed for some hours to the air in a soft and moist state; and 4thly, they are at last dried over charcoal fires. The difference in the manufacture of black and green teas is therefore most marked.—*Fortune's China*.

139. Tea was first introduced into Europe by a Russian embassy at the commencement of the seventeenth century. The yearly production of tea now amounts to 500,000,000 pounds.

140. More than one half of the weight of tea-leaves consists of WOODY FIBRE; a substance insoluble in water, and without a particle of nutriment. The black teas contain more of this fibre than the green. They sometimes contain as much as sixty-five per cent.

141. If to an infusion of tea, a solution of a salt of iron is added, the mixture turns black as ink. This well-marked property is owing to a peculiar principle, to which the name of TANNIN has been given, because it is essential to the conversion of the skins of animals into leather. The astringent

flavor of tea is owing principally to this tannin, of which green tea contains as much as 17 per cent. As a rule, the longer tea stands, or, to speak more correctly, the longer it is in contact with boiling water, the more astringent does it become. At the same time, a large amount of *extractive*\* is drawn out of the tea, and renders it stronger ; but, inasmuch as its fragrance is owing to the presence of a volatile oil, the longer the tea is allowed to *draw*, the less pleasant becomes the taste.

142. *THEIN*, the peculiar principle of tea, crystallizes in fine white prisms of a silky lustre. It is a definite compound of carbon, nitrogen, hydrogen, and oxygen. Its formula is  $O^{16} N^{10} H^2 O^4$ . When common tea-leaves are placed on a watch-glass, loosely covered with blotting-paper, and heated on a hot iron plate gradually to the point at which browning takes place, long white shining crystals appear on the paper and on the surface of the leaves. This is *thein*.

143. To make a good infusion of tea, M. Soyer recommends heating the tea in a dry tea-pot, before the hot water is added. Excellent as this plan undoubtedly is, only a small portion of boiling water should be poured on the tea, until the leaves have become fully expanded, and not until then should

\* The name *extractive* is one commonly given to all the innumerable vegetable substances not thoroughly examined, which possess a more or less dark color, and do not crystallize. Extractive is soluble in water, and generally possessed of the taste and the medicinal effect of the plant from which it has been taken. It is usually distinguished as bitter extractive in aloes, as sweet in liquorice, and so forth.

the remainder of the water be added. From three to five minutes is long enough for the tea to *draw*. All that is really good for health will be extracted in that time.

144. The adulterations of tea are numberless. As it may interest the reader to know how *green* tea is usually prepared for the English market, the following information has been gleaned for his satisfaction from "Fortune's China" :—" The superintendent of the workmen makes a mixture, in the proportion of four parts of burnt gypsum to three parts of Prussian blue, which forms a light-blue powder ready for use. About five minutes before the tea is removed from the pans, he scatters a portion of the coloring matter over the leaves in each pan; the workmen then turn the leaves rapidly round with both hands, in order that the color may be equally diffused. In every hundred pounds of colored tea will be found half a pound of Prussian blue and gypsum." One day, an English gentleman, in Shanghai, being in conversation with some Chinese from the green tea country, asking them what reasons they had for dyeing the tea, and whether it would not be better without undergoing the process, they acknowledged that tea was much better when prepared without having any such ingredients mixed with it, and that they never drank dyed tea themselves; but justly remarked that, as foreigners seemed to prefer having a mixture of Prussian blue and gypsum with their tea, to make it look uniform and pretty, and as these ingredients were cheap enough, the Chinese had no objection to



supply them, especially as such teas always fetched a higher price. Not to speak of the folly, would that all adulterations of food were equally harmless!

145. COFFEE belongs to the same natural family as ipecacuanha, quinine, and the plant from which Turkey-red is obtained. The *Coffea Arabica*, the coffee plant, will, however, be admitted to be the head of the family. It is a native of the Ethiopian highlands, but is now extensively grown in Arabia and the East and West Indies. Its height is about sixteen feet; the flowers are white and fragrant, but they fade rapidly. The fruit somewhat resembles the cherry, and grows, like the flowers, in clusters; when ripe, it is shaken from the tree, and laid on mats exposed to the sun; and when dry, it is spread upon a floor, and the husks are broken off by a heavy roller. The berries are then winnowed and further exposed to the sun. Each plant will yield from one to two pounds.

146. Coffee was first introduced into England in the year 1652, when a coffee-house was established in London by a Greek in the neighborhood of Cornhill.

147. Coffee contains about 70 per cent. of woody fibre. The *coffee-bitter*, or extractive, is a brown transparent substance, soluble in water, and having the characteristic bitter taste of the raw coffee bean. The coffee beans also contain gum and resin, and a small quantity of a fragrant volatile oil.

148. CAFFEIN is the principle which characterizes coffee. It is analogous in composition to *thein*; symbol  $C^{16} N^{10} H^2 O^4$ . It forms white silky crystals,

soluble in boiling water. It is very volatile, and is best obtained from coffee-roasters on a large scale.

149. According to Cadet, coffee, if roasted to a pale brown color, loses 12·3 per cent., if to a chestnut-brown, 18·5 per cent. in weight.

150. The *flavor* of coffee depends upon the *roasting*, and the mode of *making* the beverage. The coffee should be mixed with a little brown sugar, and well, but rapidly, roasted in close vessels, at a temperature of 482°. It should be ground into fine powder immediately before it is required for use. Should the coffee beans have been roasted some time, the flavor of the infusion will be much improved by re-roasting them for a few seconds. The best coffee can only be obtained from freshly-roasted beans.

151. Opinions vary as to whether the coffee should be boiled or infused. If an agreeable flavor be desired, the more quickly the boiling water filters through the finely-ground and freshly-roasted coffee, the better. It is, however, necessary to use a larger quantity of coffee in this case, than when it is boiled. Boiled coffee is darker colored, contains more bitter extractive, is less fragrant, and more acid than infused coffee, and is, moreover, apt to be thick. A little isinglass will, however, quickly clarify it.

152. "Persons of weak or sensitive organs will perceive, if they attend to it, that a cup of strong coffee after dinner instantly checks digestion. It is only when the absorption or removal of it has been effected, that relief is felt. For strong diges-

tions, which are not sufficiently delicate re-agents to detect such effects, coffee after eating, serves, from the same cause, to moderate the activity of the stomach, exalted beyond a certain limit by wine and spices. Tea has not the same power of checking digestion."—*Liebig's Letters*.

153. COCOA.—The cocoa tree (*Theobroma cacao*) grows wild in several countries of the torrid zone of America, especially in Guiana, Mexico, and on the coast of Carraccas. The fruit is a large coriaceous (leathery) capsule, having nearly the form of a cucumber, the seeds of which furnish the buttery, slightly bitter substance, called *cocoa*. It is now cultivated chiefly in Central America, and in British, French, and Dutch Guiana. In the West India Islands, the cultivation of cocoa has given place to that of sugar and coffee.—*Johnston's Physical Atlas*.

154. Cocoa contains a kind of fat called sometimes *vegetable butter*, which is white, of a peculiar odor, and of the consistency of tallow. It consists chiefly of *stearin* and *olein*; it is, therefore, in composition very similar to tallow. This fat disagrees with many people, but it may be easily removed if the cocoa be prepared over night; the solid fat being skimmed off in the morning, before it is boiled over again. What is called *homœopathic cocoa* is entirely freed from fat.

155. Cocoa, like tea and coffee, contains a principle peculiar to itself. It is extracted in the same manner as *caffein*, and has a similar taste. **THEOBROMIN** is a white crystalline substance; its formula

is  $C^{14} N^8 H^4 O^4$ . It may be prepared indifferently from cocoa or chocolate. The latter contains sugar, and frequently flour or starch, intimately admixed with the pounded nuts. It forms a wholesome and very nourishing aliment, especially valuable to travellers. In the early Spanish colonies of America, chocolate was considered, not as a luxury, but as a necessary article of sustenance. Of tea, coffee, cocoa, and chocolate, the two latter can alone be said to be nutritious. That term cannot be applied, in any degree, to coffee or tea.

156. The most curious characteristic of these beverages is, that they all contain principles so similar in composition. For, although *theobromin* differs from *thein* and *caffein* in some respects, yet these principles occur only in beverages employed for the purposes of refreshing and gently stimulating the system. Liebig has shown all three to be closely related to *taurin*, a principle in the bile; and what renders the opinion of this sagacious chemist more probable is, that they all contribute to the formation of bile.

157. SUGAR must next engage our attention, as it is employed to sweeten all our morning beverages. The sugar-cane (*saccharum officinarum*) is the plant from which it is obtained. Before the time of the Crusades sugar was cultivated in Europe, and, though on a very small scale, it is still grown in Valencia and Granada. The plant was found growing wild in many parts of America, at the time of the discovery of that country by Columbus; and it has flourished on the coasts of China, and in the

islands of the Pacific, from the remotest ages. The produce of certain districts, however, is of especial importance for the supply of Europe. These are, in the New World, the West India Islands, Guiana, and Brazils; in the Old World, Mauritius, Bourbon, Bengal, Siam, Java, the Philippine Islands, and China (Johnston's Atlas). Cane-sugar occurs likewise in the juice of the maple, of beetroots, carrots, turnips, potatoes, and in the nectaries of most flowers.

158. The cane, when ripe, is cut off at the root, stripped of its leaves, and passed twice through a mill, for the purpose of expressing the juice. To prevent fermentation, a portion of lime is mixed with the juice, which is then quickly evaporated in boilers. As soon as it is found, on trial, to be sufficiently evaporated, it is transferred into large, flat pans, or coolers; here the crystals soon separate from the *molasses* or *treacle*, the latter being nothing else than a concentrated solution of uncrystallizable sugar. The sugar itself is packed into hogsheads, and brought to this country, under the name of *muscovado* or *raw sugar*.

159. The process of refining consists in removing the coloring matter and other impurities from the raw sugar. A strong solution of the latter is made in water, and the serum of blood, or white of egg, is added. Now it need scarcely be told that white of egg, when heated to a certain extent, becomes solid, or coagulates; and as the serum of blood also contains *albumin*, or albumen, like white of egg, and the one cannot be distinguished from the other,

they may be employed indifferently for the same purpose. On applying heat, the albumin curdles and forms a complete network, which rises to the surface, carrying all solid impurities with it. This is skimmed off, and the sugar solution filtered through animal charcoal, which entirely removes all color. It is then quickly evaporated in a vacuum, or at least under greatly-diminished atmospheric pressure, by which means exposure to a temperature sufficiently high to injure the sugar is avoided. As soon as the sugar is capable of being drawn into threads, it is carried to the *coolers*, and agitated with wooden oars till it granulates. Upon this agitation in the cooler, the whiteness and fineness of grain in the refined sugar depend. While the sugar is in this state, it is poured into conical earthen moulds, closed at the apex of the cone, a small hole, however, being left, into which is inserted a paper plug which has previously been soaked a night in water. When these moulds are sufficiently cold, the paper-stops are removed from the points of the moulds, which are set, with the broad ends upwards, upon earthen pots, to drain. As soon as the uncrystallizable syrup has been drained off by various processes, the *sugar-loaf* is baked in an oven, heated to a temperature of 95°.

160. In making *sugar-candy*, the boiled sugar, instead of being put into coolers, is poured into pots, across which threads are strained; to these threads, crystals in form of six-sided presses (fig.15) attach them-

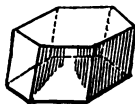


Fig. 17.

selves; the pots are then set in a stove, great care being taken not to disturb the liquid, as upon this depend the largeness and beauty of the candy. (Brande.)

161. *Barley-sugar* is nothing more than melted sugar.

162. These lumps of sugar, or the brown sugar, which we consume at our breakfast-table, of what do they consist? Chemistry offers this simple solution. Pure sugar is carbon, combined with the elements of water. The formula of crystallized cane-sugar is  $C^{12} H^{11} O^{11}$ . The presence of carbon, a simple experiment will prove:—take a lump of sugar, moisten it with hot water in a tea-cup, and pour some drops of oil of vitriol (sulphuric acid) upon it. It will immediately blacken and swell; great heat will be evolved, and the lumps of sugar be resolved into a lump of *charcoal*.\* The cause of this change is, that oil of vitriol, having very great attraction (affinity) for water, compels the elements of water contained in organic substances to unite, in order to satisfy this propensity.

163. In addition to treacle, there is another description of sugar, which we sometimes use to spread upon bread, viz.:—*HONEY*. Now, cane-sugar is found in the nectaries of flowers. This is collected by bees, and by them converted into *honey* and *wax*; that portion of the sugar which is not required for nutriment, the bee returns into the combs, in the form of a yellow syrup, the smell and taste of which

\* The experimentalist must be careful not to touch it with his fingers, until the charcoal has been thoroughly washed in water, and all the acid removed from it.

varies according to the age of the bees, and the nature of the flowers from which the bees have obtained the sugar. Honey contains two kinds of sugar. The solid granular part of the honey is of the same composition as *grape-sugar*. The latter may be best seen in old raisins, which are commonly covered with its crystals. A more correct name than *grape-sugar*, however, is **GLUCOSE**, or *sugar of fruit*, (from γλυκός, glukus, sweet) because it is the sweetening principle of all kinds of fruit, and not of the grape alone. In composition, it differs from cane-sugar only in containing a larger quantity of the elements of water in chemical combination. Its formula is  $C^{12} H^{14} O^{14}$ . The liquid part of the honey contains an uncrystallizable sugar. In addition to these, honey contains—a yellow coloring matter, wax, and gum.

164. The next object on the breakfast-table, that demands attention, is **MILK**. It is of great importance, its composition being such, that it is capable of supporting animal life, without any other food. It varies much in quality, according to the nature of the fodder on which the animal is kept, and other circumstances. Thus, for example, the more active the exercise taken by the cow, the smaller is the per-centage of butter, and the larger the per-centage of cheese.

165. To the naked eye, milk appears to be a uniformly white solution. But this is an optical illusion. Under the microscope, it is seen to consist of a perfectly transparent fluid, in which float about numberless transparent globules of fat. These, by



reason of their lightness, have a tendency to rise to the surface, where they collect, and in time, form a film or layer of a different character from the fluid beneath; this film or layer is the *cream*, the subjacent liquor the *skim-milk*. This separation appears to take place most completely in a cool temperature, from 54° to 60° F.

166. According to Berzelius, cream consists of :

Butter	. . . . .	4.5
Casein	. . . . .	3.5
Whey	. . . . .	92.0

---

100.0

167. Milk, is in fact, a natural *emulsion*; that is to say, a mechanical mixture of fatty and other matters with a watery solution.

168. BUTTER is obtained from cream by churning. By agitation, the fatty globules cohere and separate from the watery portion in larger or smaller lumps. The fluid which remains is the *butter-milk*. In the course of the agitation which the cream undergoes in churning, the delicate, elastic, transparent pelli-  
cles of albumin which surround the globules, give way, and the globules of butter, being no longer prevented by the skin, are left free to cohere. The time required for the process is dependent upon various circumstances. The temperature should be as near 55° as possible, so that in summer a cool, in winter a warm place is chosen for the operation. On being taken out of the churn, the butter is kneaded and pressed, and washed under water, in order to free it as much as possible from the butter-

milk and curd which it always contains, and to the presence of which is to be ascribed the speedy alteration which butter undergoes in warm weather.

169. Fresh butter presents the appearance of a yellowish fat, of peculiar taste and odor. The fatty matter which constitutes the *chief* part of its weight, consists of materials similar to those of other fats, viz., of *margarin* and *olein*. *Margarin* gives solidity to the butter.

170. The oily part of butter does not consist of olein alone, but is a mixture of that substance, with about three per cent of BUTYRIN, which gives to butter its taste and smell. Butyrin derives its name from *βούτυρον* (bouturon), butter: it is very liable to become sour, and to be converted into *butyric acid*, which makes butter become rancid. Its formula is  $C^6 H^7 O^3, HO$ . Butyric acid is a colorless, transparent, oily liquid, of a sharp acid taste. Being very soluble in water, it may be removed from butter by repeated washings with hot water.

171. Butter also contains certain *acids* in minute quantities, known by the name of CAPRIC, CAPROIC, and CAPRYLIC acids. They do not exist in a free state, but in combination with glycerin.

172. Butter is usually salted in order to make it keep. It may be preserved quite fresh for a long time, by covering it with syrup, without the addition of any salt, and the syrup may be washed off it when the butter is required for use.

173. The water of milk holds in chemical solution a considerable per-centage of curd, or CASEIN: the latter being dissolved by the soda contained in

all fresh milk. It serves for the formation of the blood, and for the nutrition of the animal tissues. *Cheese* is a mixture of casein with a greater or less quantity of butter.

174. Milk, when left to itself, as every one knows, becomes sour, and curdles. This is owing to the fact, that the SUGAR OF MILK (LACTIN), which gives sweetness to it, becomes converted into an acid. This *lactic acid* combines with the soda, which holds the casein in solution; and, as the latter is insoluble in water, the milk separates into so-called *curds* and *whey*.

175. Sugar of milk is an important constituent of milk; it is obtained in large quantities by evaporating *whey* to a syrupy state, and purifying the lactin, which slowly crystallizes out, by animal charcoal. It forms white crystals of great hardness. It is with difficulty soluble in cold water, requiring for that purpose six times its own weight; it has a feeble sweet taste, and feels gritty between the teeth. Formula  $C^{12} H^{12} O^{12}$ . Sp. gr. 1.54.

176. After the cream has been removed, there still remains a per-centage of cheese, as the following analysis of skim-milk will show :—

Water . . . . .	92.87
Curd, casein or cheese . .	2.80
Sugar of milk . . . . .	3.20
Ash . . . . .	0.83

Skimmed milk will, therefore, likewise curdle on exposure to air.

177. The whey still further contains a substance similar to white of egg, and various salts. The latter consist chiefly of phosphate of lime and mag-

nesia (bone earth), common salt, a salt of potass, soda, and phosphate of iron.

178. The composition of fresh cow-milk will now be intelligible, and will enable us to appreciate its value as an article of food. It consists of, in every 1000 parts—

Water . . . . .	873·00
Butter . . . . .	30·00
Casein . . . . .	48·20
Lactin . . . . .	43·90
Phosphate of lime and magnesia .	2·73
Phosphate of iron . . . . .	0·07
Chloride of potassium . . . . .	1·44
Chloride of sodium . . . . .	0·24
Soda, combined with casein . .	0·42

---

1000·00

179. Of the more substantial articles of consumption at the breakfast-table, **BREAD**, as the most important, first claims notice.

180. The valuable grain which we call *wheat*, is the produce of several kinds of the genus *Triticum*, winter wheat and spring wheat (*Triticum hybernum* and *Triticum æstivum*), being the most common. Wheat, like rye, oats, barley, and rice, belongs to the natural family. *Graminaceæ* (grasses)—a family which includes some of the most useful and the longest cultivated plants in Europe. Many indications, botanical as well as historical, warrant the presumption, that Tartary and Persia are the native countries of wheat, rye, and oats ; this, however, is uncertain.

181. In wheat, rye, &c., STARCH constitutes the principal part of the grain. Indeed, next to wood, starch is the most abundant product of the vegetable kingdom, and from it the wood itself is formed. To obtain starch from wheat, the grain is either coarsely ground, and mixed with water in large tubs ; or it is put to steep in sacks, until it becomes so soft, that the process of kneading suffices to set the starch at liberty. It must not, however, be supposed that ordinary starch is prepared from wheaten flour, though it may be made from it in the manner described. On a small scale, starch may be obtained from wheat, by mixing up dough with water, and washing it on a linen cloth with water. A milky liquid passes through, which, when set aside, deposits the starch in form of a white powder. Pure starch is a white substance, half-again as heavy as water, and insoluble even in boiling water, in which it becomes thick and gelatinous, having the *appearance* of solution, owing to the bursting of the little sacs in which each granule is enveloped. In composition, starch differs but little from, and is very easily converted into, grape-sugar. This will be more readily perceived by comparing the composition of both :—

	C	H	O
Grape sugar . . .	12	14	14
Starch . . . . .	12	10	10

Thus, by combining with four atoms of each of the elements of water, this change is effected.

182. Starch, from its ready convertibility into *sugar*, is well adapted for carrying on those changes

which occur in the juices of vegetables; and stored up, as it is, in the seeds, roots, and pith of plants, it supplies, by its decomposition, the materials for many of the most essential vegetable products. It furnishes, likewise, an important article of food, supplying the material for keeping up respiration, and the animal heat of the body. The fat of man and animals is, in all probability, derived from starch. The average per-centage of starch is as follows :—

In Wheat flour	. . .	39 to 77
„ Rye flour	. . .	50 to 61
„ Oatmeal	. . .	70 to 80
„ Rice flour	. . .	84 to 85

183. The most important nutritive element of wheaten bread is a nitrogenized substance—GLUTIN or GLUTEN. This is obtained, with great facility, by simply kneading a mass of dough under a small stream of water, by which the starch, as before described, is carried off, leaving in the hand a greyish, glutinous, highly-elastic substance—the gluten of chemists. The adhesiveness of gluten is owing to the presence of a very sticky substance, called GLIADIN.

184. The washings, collected and allowed to stand, soon become clear; the starch which was suspended in the liquid subsides, accompanied by flakes of an animalized matter. If the clear liquor be decanted and boiled, a *white froth* appears upon its surface, which, when skimmed off, has the appearance of coagulated *white of egg*, and possesses the same properties, as well as the same composi-

tion. The water from which the ALBUMIN is separated, contains all the still *soluble* portions of the flour. On evaporation, we find substances resembling *gum* and *sugar*, together with *saline matters*: these latter aid in the formation of bones.

185. The per centage composition of the *glutin* and *albumin* of wheaten flour is as follows:—

Carbon . . . . .	53·5
Hydrogen . . . . .	7·1
Nitrogen - . . . .	61·0
Oxygen . . . . .	22·0
Phosphorus . . . . .	0·4
Sulphur . . . . .	1·6

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100·0

186. Including all the nitrogenized substances of the grain of wheat under the head of *glutin*, we find it to vary from eighteen to even as much as thirty-five per cent. of the whole. Twenty per cent. may be considered a fair average.

187. In making bread in the ordinary way from wheaten flour, the yeast added to the dough changes the sugar, which, as we have seen, the flour naturally contains, into *alcohol*\* (spirits of wine) and *carbonic acid gas*. The latter forces the tough dough into bubbles, which are still further expanded by the heat of the oven, which at the same time dissipates the alcohol.

188. *Leaven* is merely dough in a state of incipient putrefaction. When, therefore, it is mixed

\* The change will be explained in the chapter on fermentation.

with a quantity of fresh dough, the same process of change takes place as when yeast is employed. It is, however, but little used now, as it frequently communicates a disagreeable odor and a sour taste to the bread.

189. In making bread, a still further change is occasioned. By the heat of the oven, a portion of the starch becomes converted into DEXTRIN (called also *British gum*), a substance easily soluble in water, and therefore more digestible than starch. That this formation really does take place, may be easily proved by wetting, with a moist sponge, the exterior of a loaf of bread, and returning it to the oven. After a few minutes, the crust will be found quite shining, as if covered with gum. The water has brought out a portion of the dextrin. In making *toast*, very much more of the starch becomes thus changed, and a small portion of it, as well as of the gluten, is carbonized.

190. There are two great objections to the use of *white bread*. The preference given to very white bread, leads some bakers to use alum. The proportion of alum in a quartern loaf, is said to vary from twenty-two grains to three times that quantity. The baker is thereby enabled to use an inferior flour, which thus assumes a very white appearance; and, owing to the property possessed by alum of absorbing and retaining water, a smaller amount of flour is necessary to make up the full weight of the loaf. The natural tendency of white bread to produce constipation, is greatly increased by the use of alum. The removal of the *bran* renders the bread less nu-



trititious, for the bran is especially rich in phosphate of lime, (bone-earth) in fat, and in nitrogen. A man might live upon *brown* bread and water ; he would languish and die upon white bread and water. For young children, indeed for all persons still growing, brown bread is incomparably superior to white. The prevalence of bad teeth among us may be in part owing to our universal preference for white bread.

191. In the ordinary process of bread-making, considerable waste is occasioned by the *vinous* or *alcoholic fermentation*, and several methods have been suggested to prevent it. The one recommended by "a Physician," is based upon the fact, that when carbonate of soda is mixed, in the proper proportion, with spirits of salt (hydrochloric acid), the common culinary salt, *chloride of sodium*, is formed; the carbonic acid, being set free, expands the dough so as to form bread. It is very necessary that the soda should be equally diffused through the flour, for if it be deficient in any part, it will not rise there ; and if in another part there be too much, or little lumps of it, in that place the bread will show a yellowish spot. The best mode of mixing it, is to shake the soda from a small sieve over the meal or flour with one hand, and stir them together with the other, and then to pass the mixture once again through the sieve. The acid should then be poured into the required water, and mixed as speedily as possible with the meal, a *wooden* spoon being used for the purpose. The bread should be put into a quick oven without loss of time.

192. The prescription given by "a Physician," is as follows :—

*For White Bread*—Take of flour three pounds avoirdupois ; bi-carbonate of soda nine drachms ; hydrochloric acid (specific gravity 1·16) eleven and three-quarter fluid drachms ; water, about twenty-five fluid ounces.

193. *For Brown Bread*—Take of wheat meal three pounds ; bi-carbonate of soda, ten drachms ; hydrochloric acid (specific gravity 1·16), thirteen fluid drachms ; water, about twenty-eight fluid ounces.

194. Another method of obtaining unfermented bread, is to mix sesqui-carbonate of ammonia with the flour, of which less than half an ounce to the pound will suffice. The heat of the oven first volatilizes a portion of the carbonic acid of the carbonate, and then the rest of the carbonate of ammonia as such. Its use is perfectly harmless.

195. Bread made in the ordinary way is sometimes sour. This is owing to the formation of acetic acid (vinegar), and lactic acid (acid of milk).

196. Before concluding so important a subject, it is worthy of mention, that bread should be baked in an oven sufficiently hot to harden the sides of the cells (which are artificially formed by the escape of the carbonic acid), so as to retain their form after the loaves are removed. When bread is very rich in gluten, it requires greater heat than usual, in order to get rid of the excess of water.

197. The more uniformly porous the bread appears after baking, the more wholesome is it, and

*vice versâ*. Three pounds of flour usually retain, after baking, one pound of water. If alum be added, it will hold half a pound more water.

198. Having so fully considered the article of bread, the last element of breakfast now claims attention. Nor is it difficult to understand the nature of an EGG, and the change it undergoes in boiling. An egg-shell is composed of CARBONATE OF LIME: the addition of an acid will therefore cause effervescence arising from the escape of carbonic acid gas. On a close inspection of the shell, it will be found to be perforated in every part. These perforations or pores serve for the admission of air to the young bird during the process of hatching. The admission of air through them causes the egg, in time, to become putrid. The best mode of preserving them fresh, is to stop these pores by painting the eggs with lime, milk, or oil, and then to lay them in sawdust.

199. On breaking an egg, we first meet with a colorless liquid, contained in cells; this is the ALBUMIN\*, or *white of egg*. If it be dried at a temperature of  $120^{\circ}$ , it has the appearance of gum, and will be found to have lost seven-eighths of its original weight. But if the heat be increased to about  $160^{\circ}$ , the albumen coagulates, and is no longer soluble in water. Hence white of egg may be described in two states :—

\* Albumin has the property of being coagulated by corrosive sublimate, with which it combines, forming an insoluble compound; and is, in consequence, the best known antidote to that most fearful poison. Four grains of corrosive sublimate are said to be rendered harmless by the contents of a single egg.

200. 1. *Dry soluble albumin*, when placed in water, first swells up, and then dissolves, forming a liquid of an opal tint. It possesses the property of dissolving bone-earth, a property which enables the blood to convey to the bones their earthy parts.

201. 2. *Coagulated albumin* is insoluble in water, and yields from one to two per cent. of phosphate of lime (bone-earth).

202. Albumin contains both *sulphur* and *phosphorus*. The presence of the former causes the blackening of a silver spoon, when left in an egg for a short time, owing to the formation of black *sulphide of silver*. It has the same composition as vegetable albumin (see p. 94). Its formula is  $C^{400} H^{310} N^{50} O^{120} P S^2$ .

203. The *yolk* of the hen's egg consists of albumin mixed up with about thirty per cent. of a yellow oil: it coagulates, therefore, when heated. The oil may be removed by strong pressure. In composition it resembles most oils, and consists of carbon, hydrogen, and oxygen, in definite proportions, together with sulphur and phosphorus. It is of a bright yellow color, and has a sickly smell. The only tasty principle of the egg is the oil in the yolk.

204. When an ordinary-sized egg is boiled in water, it loses about three-tenths of a grain. Of an egg which weighs 1000 grains,

The <i>shell</i> constitutes	. . .	106·9 parts
The <i>white</i> „	. . .	604·2 „
The <i>yellow</i> „	. . .	288·9 „

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1000·0

205. In a hard-boiled egg, the albumin of the white and the yolk become insoluble in water, and less digestible.

206. Undoubtedly, the true starting-point of all the animal tissues is albumin. This appears from the phenomena of incubation, in which all the tissues are derived from the albumin of the white and of the yolk, with the aid only of the air, of the oily matter of the yolk, and of a certain proportion of iron also found in the yolk. It is, therefore, clear from this, that albumin is capable of passing into fibrine, casein, membranes, horn, hair, feathers, &c. (Liebig).

207. An attentive consideration of the various substances partaken of as food at breakfast, will suggest a division of them into two classes. We have seen that our food in some cases contains nitrogen, in others not. The casein of milk, the albumin and gluten of bread, the albumin of eggs, are substances rich in nitrogen, and serve, by the formation of flesh and blood, to increase the mass of the human frame. Butter, sugar, sugar of milk, honey, starch, and oil of eggs, are rich in carbon, and serve not only to maintain the animal heat of the body, but for the support of respiration and the formation of fat.

## QUESTIONS ON CHAPTER III.

122. What substances are treated of in the present chapter?

123. State what you know of the abundance of water?

124. What is water composed of? What is its symbol? Its equivalent? Of what is it the standard of comparison?

125. How can we prove that water is not an element?

126. At what temperature does water freeze? Which is lighter, water or ice?

127. Does water continue to contract as it cools? At what temperature does it begin to expand? What is the object of this exception?

128. What is another striking property of water? What is the distinction between soft and hard water? Do all waters contain salt? Do they contain the same amount of salt? Why does water at the Equator contain more salt than that of the English Channel?

129. To what salt is the hardness of water more especially due? What is the difference between slating and furring?

130. Of the gases with which we are familiar which is most, and which least soluble? Is this solvent power important? How does it affect fishes?

131. At what temperature does water boil? What is distilled water?

132. What is meant when a compound is said to contain the elements of water?

133. Is hard or soft water best suited for making tea? How may hard water be improved? At what temperature must the water be for making tea?

134. Where is the tea-plant found? What is the botanical name for tea? Can black and green tea be made from the same shrub? How is a tea-plantation made? What appearance has such a plantation?

135. How long is a plantation left unmolested? Does the practice of pulling the leaves injure the plants? How long does a shrub bear?

136. Is the difference in the making of green and black tea very great?

137. How is green tea made?

138. Relate how black tea is made? What then constitutes the difference in the manufacture?

139. When was tea first introduced into Europe? How much tea is annually produced?

140. How much woody fibre is contained in tea? Which contains most, black or green?

141. What is tannin? How much of it is contained in green tea? What do we mean by extractive? Is it an advantage to allow tea to draw long?

142. What is thein? Of what is it composed? How may it be prepared?

143. How does Soyer recommend tea to be made? What other precaution is advisable?

144. Relate how the Chinese manufacture green tea.

145. To what natural family does coffee belong? To what country? How is it prepared?

146. When and by whom was coffee first introduced into England?

147. How much woody fibre does coffee contain? What is coffee-bitter?

148. What is caffein? What is it composed of? What appearance does it present?

149. What changes does coffee undergo in roasting?

150. Upon what does the flavor of coffee depend?

151. Should coffee be boiled or infused?

152. What, according to Liebig, is the effect of strong coffee? Has tea the same effect?

153. From what tree does cocoa come? What is the fruit like? Where is cocoa now grown?

154. Of what nature is the fat of cocoa? In what respect does homœopathic cocoa differ from ordinary?

155. What peculiar principle does cocoa contain? What is theobromin? How is it made? What is chocolate? Is chocolate nutritious?

156. What is a curious feature in tea, coffee, and cocoa? To what substance in the bile are they related?

157. Where does the sugar-cane grow? In what plants is cane-sugar found?

158. How is the cane prepared? In what does treacle differ from raw sugar?

159. How is the refining accomplished? What is the object of blood in the purification?

160. How is sugar-candy made?

161. What is barley-sugar?

162. What is the composition of cane-sugar? How may the presence of carbon be proved?

163. What of honey? What is the nature of sugar in honey? Is it peculiar to honey or to grapes? What is the name by which it is best known?

164. What renders milk of so much importance as an article of food?

165. Is it a uniformly white liquid?

166. What is cream? What is it composed of?

167. What name would a chemist give to milk?

168. How is butter obtained? What is butter-milk? What is necessary to keep butter fresh?

169. Of what is it composed? What gives solidity to butter?

170. What is the tasty principle of butter? To what is the rancidity of butter owing?

171. What other acids does butter contain?

172. What is the object of salting butter? Can it be kept fresh in any other manner?

173. What is cheese? By what name does the curd go? What keeps the cheese in solution in fresh milk?

174. Why does milk become sour? What is the sweetening principle of milk? What do chemists call it?

175. What elements is it composed of?

176. Why does skim-milk curdle?

177. What does the whey contain?

178. What is the composition of fresh milk?

179. Which is the most substantial article of breakfast?

180. From what plant is wheat derived? To what family does it belong? What is its country?

181. What constitutes the chief constituent of wheaten



flour? How is it prepared? What are its properties? Does it differ much in composition from grape sugar?

182. Is starch convertible into sugar? In what parts of plants does starch abound? What object does it serve in the human and animal economy? Whether does wheaten flour or rice contain most starch?

183. What is the nutritive element of flour? How may it be obtained? To what is its adhesiveness owing?

184. What other nitrogenized constituent is there in flour?

185. What is the percentage composition of albumin and gluten?

186. What is the average per centage of gluten in flour? What other compounds do we find in flour?

187. In making bread, what change does the yeast induce?

188. What is leaven? Why is it not more generally used?

189. What change does some of the starch undergo in baking? Does toast contain the same principle? What do chemists call it?

190. What objections are there to the use of white bread? What is the bran more especially rich in?

191. What waste takes place in the baking of bread? Upon what principle does a "Physician" propose to make bread?

192. How may unfermented white bread be prepared?

193. Brown bread?

194. What salt of ammonia may be used?

195. To what is the acidity of some bread owing?

196. Why should bread be well baked?

197. Has the porosity of bread anything to do with its wholesomeness?

198. What is the nature of an egg? What is the shell made of?

199. What is the chemical name of white of egg? What is its property?

200. What are the chief properties of soluble albumin?

201. What are the properties of coagulated albumin?

202. How do you know that albumin contains sulphur? Does vegetable albumin differ from animal albumin in composition?

203. In what respects does the yolk differ from the white? Of what nature is oil of eggs?

204. What proportions do the yolk, the white, and the shell bear to each other?

205. What effect has long boiling upon an egg?

206. What is the true starting-point of all the tissues? In the case of an egg, into what is albumin convertible?

207. Into what two classes may our food be subdivided? What constitutes the difference in each case?

## CHAPTER IV.

### CHEMISTRY OF FERMENTATION.

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208. It may be laid down as a general principle in Chemistry, that the more simple a substance is, as regards its constitution, the more stable will it be, and *vice versâ*: that is to say, the liability of a body to undergo change is exactly in accordance with its constitution. Only organic substances are capable of fermentation; and these, whether derived from the vegetable or animal kingdom, are remarkable, as a class, for their complex forms. And yet the number of elements which compose them is extremely limited! Very few of them contain more than three, viz. Carbon, Hydrogen, and Oxygen. In the previous chapter on Breakfast-table Chemistry, all of them are incidentally mentioned; and, in fact, it is impossible to speak of the theory of *bread-baking* without entering slightly upon the subject of fermentation.

209. STARCH, CANE-SUGAR, and GRAPE-SUGAR, are the compounds which are capable of *vinous\* fermentation*, that is to say, of undergoing a process in which spirits of wine, or alcohol, is formed, as is the case in making wine and beer. Of these, starch

\* From vinum, wine.

and cane-sugar must first be converted into grape-sugar before they can ferment.

210. It will be remembered that *grape-sugar* is not peculiar to the fruit of the vine, but that it is the sweetening principle of all fruits, and that *glucose* is, therefore, the more appropriate designation. It is less soluble in water, and less sweet, than cane-sugar, and crystallizes in a different manner.

211. A solution of perfectly pure grape-sugar in water may be kept for any length of time, without the formation of alcohol. But if it be mixed with white of egg, flour-paste, or blood, in a *state of decomposition*, then ALCOHOL and CARBONIC ACID will be formed at the expense of the sugar. Now, although neither alcohol nor carbonic acid is to be found in sugar, yet it contains the elements which constitute these substances. The composition of grape-sugar is :—

Carbon . . . . .	36.4
Hydrogen . . . . .	7.0
Oxygen . . . . .	56.6

---

100.0

Pure, or absolute alcohol, as it is called, and carbonic acid, *the bodies which are produced in the process of fermentation*, consist of—

	Alcohol.	Water.	Carbonic Acid.
Carbon . .	52.19		27.27
Hydrogen .	13.02	11.1	
Oxygen . .	34.79	88.9	72.73
	<hr/> 100.00	<hr/> 100.0	<hr/> 100.00

Although it must be distinctly borne in mind that sugar contains no alcohol, yet, because it becomes changed by a ferment into alcohol, and carbonic acid, we may assert, for the sake of simplicity, that one hundred parts of glucose consist of :—

Alcohol. . . . .	46·46
Carbonic Acid . . . .	44·45
Water . . . . .	9·09
	<hr/>
	100·00

212. It has been said that solutions of pure sugar cannot ferment; but in fact, no such solutions exist in nature. The juices of all fruits contain *within themselves* the elements necessary for the production of vinous fermentation.

213. Now, it may be fairly asked, what is understood by a *ferment*? It is a certain form of matter in a state of *change*, which change it is capable of communicating. All ferments contain nitrogen, and are in a state of decomposition. Fresh white of egg, for example, is not in itself a ferment; but when, by the action of the air, it becomes putrid, an alteration in its character takes place. Not only does it become changed in character, but it is capable of inducing a similar kind of change in compound bodies, such as sugar, with which it may be brought into contact. Ferments are, therefore, contagious; or, in other words, capable of propagating their state of change. Fermentation is a process of change, occasioned by a new arrangement of the elements of a compound. The name is derived from *fermentum*, that which is light and puffy; originally

applied to the process by which alcohol is formed in liquids containing sugar.

## CHEMISTRY OF WINE.

214. The juice of the grape, *Vitis vinifera*, consists mainly of *water*, holding in solution—*grape-sugar*, *albumin*, *cream of tartar*, a *coloring matter*, an *oil*, and a small quantity of *tannin*. It is obvious, therefore, from the presence of albumin, that grape-juice can ferment of itself. The proportions in which these various constituents of the juice exist in the grape, vary according to climate, culture, and the nature of the soil.

215. Few crops are so much at the mercy of the atmosphere as the vine; even in the most favorably situated vineyards, it is rare that wines of equal quality and flavor are produced in two successive years. A hot summer is naturally favorable to the vine; but, besides the sustained heat, which is necessary during the whole year's growth, it would appear that a mild autumn is a necessary condition to the ripening of grapes. The cultivation of the vine would be altogether ruinous, were it not for the circumstance that the value of wine increases in a much greater ratio than its quality, so that one good year often indemnifies the grower for many bad ones, and that the vine grows and thrives in situations where it would be difficult to rear anything else. The produce of a vineyard depends also upon its age. Official documents, whilst they give the mean produce of the vine, for the whole of France, at 171 gallons per acre, state the

whole of the wine produced over the country at 976,906,414 gallons. The produce of the vineyards of the German States brought to market, appears to be 59,180,000 gallons. (Boussingault).

216. In making wine, the *juice* of the grape is put into vats, or barrels, and left to itself. The *albumin* which it naturally contains, acted upon by the oxygen of the air, soon decomposes, and acts as a ferment upon the sugar. *Alcohol* is formed in the liquid, which becomes changed into wine, and *carbonic acid* is given off in such enormous quantities, as to require some care in the overlookers. As when fermentation has once set in, the access of air is not only no longer necessary, but is rather injurious than otherwise, it is the custom in some countries to pass the gas by means of a tube connected with the spunt of the barrel, into a solution of potash or soda-ash; thus, not only is the poisonous carbonic acid removed from the air, but a useful salt (the so-called bi-carbonate of potash, or soda) is obtained by its union with the potash, or soda.

217. It has been mentioned that grape-juice contains cream of tartar, a combination of two eqs. of tartaric acid with one eq. of potash. This acid salt, which chemists call *bi-tartrate of potash*, though soluble in water, is insoluble in alcohol. As fast, therefore, as alcohol is formed, at the expense of the sugar, does this salt separate in the form of a hard, crystalline substance, from which all the cream of tartar of commerce is obtained. In good vintages, when the *sugar* predominates, the formation of alcohol proceeds to such an extent, that the great bulk

of the salt is removed ; but in bad vintages much of it remains in the wine, rendering it *sour*.

218. Now, just as the juice of the grape contains an acid salt, so likewise does the juice of apples, pears, gooseberries, currants, and elderberries, from which home-made wines are prepared, though in them it is of a different character. The *malic acid* (from *malus*, an apple, because first discovered in apples) and the *citric acid* (from *citrus*, a citron or lemon) contained therein in combination with potash, are not affected by any quantity of alcohol, because they are equally soluble in water and in alcohol, and thus, however disguised with excess of sugar, these home-made wines are very unwholesome for many persons.

219. When the quantity of *sugar* predominates over that of the albumin or ferment, the result is a more or less *sweet* wine. But when the *ferment* abounds, the wine has a *dry* taste.

220. If the fermentation of grape juice be checked before it is complete, and the wine bottled, the process will be continued in the bottles. The carbonic acid gas being disengaged under considerable pressure, is retained in the wine, and thus are obtained those delicious wines, Champagne, sparkling Moselle, Hock, &c.

221. The *coloring matter* of the grape resides in the *skins*. The *juice* of both red and white grapes is nearly colorless, because the coloring of the skin is insoluble in water, but soluble in alcohol. If, therefore, *red* wine is to be made, the expressed juice is allowed to ferment in contact with the skins, until



the formation of alcohol has drawn out their coloring matter.

222. The color of dark sherry is artificial, being derived from caramel, or burnt sugar. Great fraud is practised in the doctoring of wines. Strength is given by the addition of alcohol—acidity corrected by the use of oxide of lead ; the favorite astringency of old port conferred by alum, bark, or rhatany ; further, whilst the color of wine is heightened by the use of logwood and elderberries, bouquet is conferred by certain essential oils.

223. The quantity of alcohol contained in wines varies ; the richer and riper the grape, the stronger will be the wine. Port wine and sherry contain sometimes as much as twenty-five per cent. ; other samples only sixteen per cent. The light wines of Germany and France contain from ten to fifteen per cent. Wine owes its intoxicating character to the presence of spirit.

ABSOLUTE ALCOHOL, OR PURE ALCOHOL (which may be obtained by distilling the spirits of wine of commerce with half its weight of quick-lime), is a colorless, limpid liquid, of an agreeable, though somewhat pungent, taste and smell. Its specific gravity is only  $\frac{3}{4}$  that of water, being 0.793 at 60°. It is highly inflammable, and burns with a pale blue flame, free from smoke. It boils at 178°.

225. The composition of alcohol is expressed by the formula  $C^4 H^6 O + HO$  ; it is produced by the breaking up of one equivalent of glucose ( $C^{12} H^{14} O^{14}$ ) into two eqs. of alcohol ( $2 C^4 H^6 O + HO$ ), four of carbonic acid ( $4 CO^2$ ), and two eqs. of water ( $2 HO$ ).

226. Absolute alcohol absorbs water from living tissues with such avidity that it destroys their vitality; it may therefore cause death when taken into the stomach. But these poisonous effects cease when diluted with water. Taken in small quantities, it produces a cheerful flow of spirits; in greater, intoxication.

227. Alcohol has never been frozen, even at a cold of—212° F.; hence its adaptation for the making of thermometers, by which great degrees of *cold* are to be measured.

228. Spirits of wine of commerce contains upwards of thirteen per cent. of water. Next to water, it is the best solvent with which we are acquainted. And that it is largely employed as a means of solution will be apparent from the fact, that eau de cologne and the various perfumed waters, liqueurs and cordials, tinctures and varnishes, are solutions of the various oils, resins, barks, roots, and plants, in spirits of wine.

229. The conversion of alcohol into ETHER is a change of such importance, that mention of it ought not to be omitted. It is formed by distilling equal weights of alcohol and oil of vitriol. The action of the latter will be more intelligible when we compare the composition of alcohol with that of ether.

The formula of alcohol is  $C^4 H^6 O + HO$

That of ether is . . .  $C^4 H^6 O$

Oil of vitriol has therefore only taken one eq. of water from the alcohol.

230. Ether is a colorless, transparent, fragrant,

and volatile liquid, very thin and mobile. Its specific gravity is 0.720. It is very combustible, and burns with a white flame, generating, like alcohol, carbonic acid and water. It boils at 96°. When dropped on the hand, it occasions a sharp sensation of cold from its rapid volatilization. It is miscible in alcohol in all proportions; but ten parts of water are required to dissolve one part of ether.

231. Ether resembles, in so many respects, the ordinary oxides of metals, that it is supposed to be the *oxide of an organic compound*, possessing properties similar to those of elements. This compound is called **ETHYLE**, and is represented by the formula  $C^4 H^5$  and the symbol **Ae**. According to this view, alcohol is a chemical combination of the oxide of ethyle with water; and, as definite compounds of water with other bodies are called *hydrates* (from ὑδωρ, hudor, water) so is alcohol a *hydrate of the oxide of ethyle*.

232. The fragrance of certain wines is due to the presence of an ether, the so-called *oenanthic ether*, from οἶνος (oinos) wine.

233. With reference to the use of wine, Liebig says, in his *Familiar Letters*: "As a restorative, or means of refreshment, where the powers of life are exhausted, of giving animation and energy where man has to struggle with days of sorrow, as a means of correction and compensation when misproportion occurs in nutrition, and the organism is deranged in its operations, and as a means of protection against transient organic disturbances, wine is surpassed by no product of nature or art.

234. "The nobler wines of the Rhine and many of those of Bordeaux, are distinguished above all others by producing a minimum of injurious after-effect. The quantity of wine consumed on the Rhine by persons of all ages, without perceptible injury to their mental and bodily health, is hardly credible. Gout and calculous disease are nowhere more rare. In no part of Germany do the apothecaries' establishments bring so low a price as in the rich cities on the Rhine; for there wine is the universal medicine for the healthy as well as the sick; it is considered as milk for the aged.

235. "Alcohol stands high as a respiratory material. Its use enables us to dispense with the starch and sugar in our food, and is irreconcilable with that of fat.

236. "Since the establishment of Temperance Societies, it was thought fair in many English families to compensate, in money, those servants who took the pledge and no longer drank beer; but it was soon found that the monthly consumption of bread increased in a striking degree, so that the beer was twice paid for; once in money, and a second time in its equivalent of bread.

237. "On occasion of the meeting of the Peace Congress in Frankfort, the proprietor of the celebrated Hôtel de Russie told me, with expressions of astonishment, that at his table at that time, a regular deficiency occurred in certain dishes, especially farinaceous dishes, puddings, &c.; an unheard-of occurrence in a house in which the amount and proportion of the dishes, for a given number of

persons, has been for years fixed and known. This dining-hall was filled with friends of peace, all of whom belonged to temperance unions,—some, no doubt, to vegetarian societies—and drank no wine. Herr Sarg observed that those who take no wine always eat more in proportion. In wine countries, therefore, the price of the wine is always included in that of the dinner, and it is considered just, that in hotels, people should pay for wine even when they drink none.

“O monstrous! but one half-penny worth of bread to this intolerable deal of sack!”—SHAKSPERE.”

#### CYDER AND PERRY.

238. A substitute for wine is found sometimes in the fermented juice of *apples* and *pears*. The fruit is shaken from the trees, and piled up in large casks placed in cellars. It is crushed about two months after it is gathered, and the pulp is left for ten or twelve hours soaking in the juice, in order to give to the cyder that rusty yellow color, so much esteemed. The pulp is then pressed, and the juice allowed to run into large vats, in which it undergoes vinous fermentation. After the latter process has proceeded for a month, the liquor is put into smaller barrels, in which the fermentation goes on more slowly. In time, longer or shorter, according to the temperature of the cellar, the whole of the sugar is changed into alcohol, and an agreeable, though, to some persons (for reasons which have already been pointed out,) very unwholesome beverage is obtained.

## BEER, ALE, AND PORTER.

239. In the production of *beer*, the sugar is derived from the *malt*. Not that the barley contains much sugar, but, by a singular process, the starch passes into sugar. The operation of malting is performed by steeping the barley in water, until the grains become swollen and soft; and then piling it in a heap, to favor the elevation of temperature caused by absorption of oxygen. Afterwards it is spread upon the floor, and, from time to time, turned to prevent unequal heating. As soon as the sprouting of the seed has sufficiently proceeded, it is quickly dried in a kiln, to destroy its vitality. By this operation, the nature of the starch becomes altered; four times the amount of sugar, and three times the amount of gum, originally existing in the barley, are now to be found in the malt. This change has been accomplished by means of a substance called by chemists *diastase*, brought into action by the germinating of the barley. The composition of this substance is unknown; but that it partakes of the nature of albuminous substances, and contains nitrogen, is certain. It is likewise certain that the starch, which is formed when the vegetative power of plants is most active, is dissolved, and made ready for use by this very diastase, which exists in all seeds and buds.

240. If a little malt be infused in warm water, it will convert a very large amount of starch, first into soluble starch, or dextrine, and subsequently into sugar. To prove this fact, it is sufficient to mix some gelatinous starch with a small quantity of malt-

infusion, exposing the whole to a gentle heat. In a few minutes it becomes thin, like water, and, after a few hours, will be found to contain glucose, and to be sweet to the taste.

241. In the manufacture of *beer*, the malt, thus prepared, is ground and infused in the so-called *mash-tun*, in rather more than its bulk of water, at a temperature of  $180^{\circ}$ , and is exhausted by repeated washings with fresh portions of water. The easily soluble *diastase* has thus time to act upon the undissolved starch of the grain, and to convert it into dextrine and sugar. The liquor, strained from the malt-husks, is called *wort*. This is boiled with hops, from which the so-called *lupulin* (a bitter resinous principle), and an essential oil, are extracted. The hops serve to cloak the sweetness by a pleasant bitter,\* and to give to the malt liquor, more durable properties. When the wort has been sufficiently boiled, it is thrown into large, shallow *coolers*, in which it is cooled as quickly as possible; it is then suffered to run into the fermenting vat, having been previously mixed with a small quantity of *yeast*, which instantly induces *vinous fermentation*. A great amount of froth is thrown up, arising from the escape of carbonic acid gas; the liquor loses much of its sweetness; from being turbid, it becomes clear, and acquires a new taste and intoxicating properties, from the formation of alcohol. The

\* The idea recently advanced, that Messrs. Bass & Allsopp employ strychnine to communicate a bitter taste to their celebrated and wholesome ales, is too absurd to require refutation.

fermentation is stopped by separating the yeast, and drawing off the beer into casks.

242. *Porter* derives its color from highly-dried, or charred malt, the burnt sugar of which, (caramel) communicates the color. It contains about  $4\frac{1}{4}$  per cent. of alcohol, while *Burton ale* contains as much as  $8\frac{1}{2}$  per cent. *Small beer* contains but  $1\frac{1}{2}$  per cent. of alcohol, and is a very wholesome beverage for the young.

243. Yeast, to which such frequent allusion is made, is a substance which collects as a scum and sediment, during the fermentation of the wort, and is derived from the changes which the gluten and the albumin of the malt sustain, by contact with oxygen from the air. It increases in every brew to many times the volume of the yeast originally introduced into the liquid. It is composed of egg-shaped globules (*mycoderma cerivisiae*), about  $\frac{1}{2500}$  of an inch in diameter. From its very origin, it must contain nitrogen, as only nitrogenized organic substances are capable of acting as ferments. The most remarkable property of yeast, is, then, briefly its power of changing a solution of sugar into alcohol and carbonic acid.

#### ARDENT SPIRITS.

244. The chemistry of the manufacture of these is so similar to that of brewing, and, indeed, of the vinous fermentation in general, that little remains to be said. The distiller who prepares spirit from grain, uses a very large quantity of *grain* with the malt, the *diastase* of which converts the starch of



the grain, first into dextrine, and then into glucose. The wort, or *wash*, as it is called in the language of the trade, is brought to ferment as quickly as possible, by considerable doses of yeast, and is then distilled. *Whiskey* is prepared from barley and oats. *Highland whiskey* and *Irish poteen* seem to derive their flavor from the malt being made and dried with peat, which gives out minute quantities of *creasote* and *volatile oils*. *Rum* is obtained from the fermented juice of the sugar-cane. It must, however, be remembered, that the *sugar* must first pass into *glucose*, before fermentation can commence. *Brandy*, (a word derived from the German, signifying burnt wine) is made from wine, and colored with caramel, or burnt sugar. *Gin*, *Hollands*, and *Schiedam*, are distilled from *barley*, and flavored with juniper-berries, turpentine, and other substances. The two latter spirits derive their names from the places where they are chiefly prepared. In Bengal and China, spirits are made from *rice*, a grain containing a larger amount of starch than any other natural product. *Arrack* is a spirit of this kind, and is characterised by the excessive amount of alcohol which it contains.

245. The amount of alcohol contained in gin, brandy, rum, and whiskey, varies from 40 to 50 per cent. The various flavors are due to essential oils, either generated by the act of fermentation, or purposely added.

246. "It is an exception from the rule, when a well-fed man becomes a spirit-drinker. On the other hand, when a laborer earns by his work less

than is required to provide the amount of food which is indispensable in order to restore fully his working power, he resorts to spirits. He must work; but in consequence of insufficient food, a certain portion of his working power is daily wanting. Spirits, by their action on the nerves, enable him to make up the deficient power *at the expense of his body*, to consume to-day that quantity which ought naturally to have been employed a day later. He draws, so to speak, a bill on his health, which must be always renewed, because, for want of means, he cannot take it up; he consumes his capital instead of his interest, and the result is, the inevitable ruin of his body."—*Liebig's Chem. Letters.*

247. Vinous fermentation may be induced even in milk, and a spirit is prepared from it in some few places. There is every reason for believing that the lactin, or sugar of milk, first passes into glucose before the alcoholic fermentation commences. Certain it is that the lactin disappears in milk exposed to a sufficient temperature, with the same phenomena as characterise the fermentation of the other sugars; viz. the disengagement of carbonic acid, and formation of alcohol.

248. In the case of milk becoming sour by exposure to the air at the ordinary temperature, its casein, by combining with oxygen, passes into a state of decomposition (forming a ferment), which induces the so-called LACTIC ACID FERMENTATION. The acid which is found in the fermented juice of beet-root, carrots, and turnips, in sour-kraut, and

in several animal liquids, is nearly pure lactic acid. It is formed in saccharine or starch-holding liquids, without the intervention of either alcohol or air; and when once begun, it will go on by itself. Lactic acid, when pure, forms a colorless, syrupy liquid, of sp. gr. 1.215. It possesses an acid taste, and is soluble in water, alcohol, and ether. It dissolves in cold milk without any change until heat is applied, when coagulation ensues; and this explains a common phenomenon in culinary experience, of apparently sweet milk coagulating at once when boiled. The difference of composition between lactic acid and lactin will be apparent by a study of their formulas:



When lactic acid unites with oxides, *lactates* are produced.

249. The *state* of decomposition in which the ferment exists, may induce either the lactic acid or the vinous fermentation. Thus, the glutino-albuminous matter of malt, when suffered to putrify in water for a few days, acquires the power of converting the accompanying sugar into lactic acid; while, in a more advanced state of decomposition, it converts the sugar into alcohol. And again, if wheaten flour be made into a paste with water, and left four or five days in a warm place, it becomes a *lactic acid ferment*; if left two or three days longer, until it has become more putrid, it proves a *vinous ferment*.

250. From ancient times it has been known that the juices of fruit, after becoming vinous from fer-

mentation, were subject to another change, by which they became sour to the taste. Under the name of *vinegar* this acid was in common use among the Egyptians long before the time of Moses.

251. The process used to be called the **ACETOUS** or **ACETIC ACID FERMENTATION**, although, properly speaking, it has nothing in common with the vinous fermentation; for, whilst the presence of oxygen (or of air) is absolutely essential to the formation of acetic acid, the vinous fermentation, when once commenced, is better carried on with exclusion of air.

252. All liquids capable of vinous fermentation may be made to produce vinegar. In all such liquors the sugar is first, by fermentation, converted into alcohol, and afterwards, by oxidation, into acetic acid.

253. The nature of the formation of acetic acid from alcohol is very intelligible, as the following diagram will prove:

Alcohol . . . . .  $C^4 H^5 O + HO$

Acetic acid (strongest)  $C^4 H^3 O^2 + HO$

It is obvious, therefore, that acetic acid is formed by the oxidation of alcohol; or, to speak accurately, acetic acid is produced from alcohol by the substitution of 2 eqs. of oxygen for 2 eqs. of hydrogen.

254. And yet pure alcohol will no more become acetic acid by simple exposure to air, than will a solution of pure sugar change into alcohol and carbonic acid. A *ferment* is necessary, which only acts by the power it possesses of causing the alcohol

to obtain oxygen from the air. In fermented liquors, the alcohol being mixed with certain organic substances at a proper temperature, quickly disappears, and is replaced by acetic acid. In such cases the ferment absorbs oxygen from the air, and transfers it to the alcohol.

255. The best vinegar is made from *wine*. In wine-countries inferior wines are employed for the purpose. The wine is mixed with a little vinegar, and exposed to the air in casks, partly filled with the pressed husks of grapes. From time to time the liquid is drawn off below, air supplies its place, the husks become warm by absorbing oxygen, which they yield to the alcohol when the liquid is again poured into the vessel. This process is repeated until the vinegar is made. Its strength may be indefinitely increased by the addition of more or less brandy to the wine. Free access of air, a temperature not below 75°, and exposure of a large surface of liquid, are chief conditions in the formation of vinegar.

256. It is also frequently manufactured by the so-called *quick vinegar process*. Casks, perforated to admit air, are filled with beechwood shavings, moistened with vinegar. A mixture of one part of spirits, five of water, and  $\frac{1}{1000}$  part of yeast, or honey, is allowed to drop continuously through the casks: the temperature rises to 100°, and the whole of the spirit, by passing two or three times through the shavings (which offer a very extended surface to the action of the air), is, in 26 to 36 hours, converted into vinegar.

257. The greater proportion of our English vinegar is made from malt, somewhat in the following manner:—Good malt is mashed, first with warm, then with hot water; the wort, mixed with yeast at a temperature of 75°, soon begins to ferment. In about 36 hours the wash is racked off into a cask set on end, which is sometimes provided with a false bottom pierced with holes, and placed about a foot above the true one. On this bottom a quantity of rape, or the refuse raisins, elderberries, &c., from the making of British wines, is laid. A further quantity of yeast having been added, the malt liquor becomes warm in the course of 24 hours, and is then racked off into another similar cask. After some time this racking process is discontinued, and the vinegar is allowed quietly to complete its formation, a proper temperature (from 70° to 77°) being always kept up, by placing the cask in a warm situation.

258. Vinegar is sometimes prepared from sugar, as well as from souring beer and cyder. The flavor of the best kinds of vinegar is due to *acetic ether*. The vinegars from wine, beer, and malt contain, in addition to acetic ether, all the foreign matters pertaining to these various liquids.

259. But besides the oxidation of alcohol, there is another means of obtaining vinegar—viz., by the distillation of hard wood, as oak and beech, in iron cylinders. The flavor of *wood-vinegar*, or *pyroligneous acid*, is peculiar, reminding one of tar and creasote.

260. The taste of wine vinegar being so much

more agreeable than that of all others, it is a practice to render the common liquids more palatable for domestic use, by adding a little cream of tartar for the taste, burnt sugar for the color, and fine brandy, or acetic ether, for the aroma. To such additions, no rational objection can be made: but we protest against the adulterations of vinegar, which have been so ably exposed by *The Lancet*. The use of small quantities of sulphuric acid, which was sanctioned by the Excise, to counteract the tendency of common vinegars to become putrid, has led unprincipled dealers to employ large quantities, in order to produce that degree of acidity, which the acetic acid of vinegar should confer. A good vinegar, employed in small quantities, promotes the digestion of substances like salads, rich in albumin. A spurious vinegar, adulterated with sulphuric acid, injures the coats of the stomach.

261. Vinegar, from whatever source derived, when freed from all impurities, and from all extraneous water, forms acetic acid.

262. *Pure hydrated acetic acid*, or *glacial acetic acid*, ( $C^4 H^3 O^3 + HO$ ) is a clear, colorless liquid, very sour and pungent, miscible in all proportions with water, and of a sp. gr. of 1.063. It distils without change, and combines, with the various oxides or bases, forming salts called *acetates*, most of which are soluble in water, as well as in alcohol.

263. Dilute acetic acid occurs more frequently in nature than any other organic acid. It exists in the sap of many plants, and in some liquids. It is

also formed in the decay and putrefaction of various animal and vegetable substances.

264. It has been thought desirable to devote a separate chapter to the consideration of the Chemistry of Fermentation, partly because of the great interest it possesses as a branch of household chemistry, and partly on account of the important position which the manufacture of fermented liquors occupies in all civilized communities. From the earliest times of which we possess records, the application of the principles of fermentation to the preparation of beverages of more or less intoxicating qualities, seems to have been generally understood. Like all other gifts of God to His creatures, that of wine, "that maketh glad the heart of man," has been greatly abused; nevertheless, though there are many philanthropists who would, on that account, entirely banish from society the use of all fermented liquors (with the exception, perhaps, of vinegar), it seems scarcely to admit of doubt, that when used in moderation, they add materially to the reasonable enjoyment of mankind. At any rate, so long as they occupy the prominence among articles of consumption, which they unquestionably do at the present day, a few pages devoted to their consideration can scarcely be thought out of place in a work like the present. The consideration of the chemistry of fermented liquors, moreover, is a very natural introduction to that of the *dinner-table*, to which they form so general an adjunct, and which will be the subject of the next chapter.



## QUESTIONS ON CHAPTER IV.

208. Has the composition of a substance anything to do with its stability? What may be stated as a rule in chemistry? What substances can ferment? What is the characteristic of fermentable organic substances? What three elements do they contain?

209. What are the most notable substances capable of fermentation? What does vinous fermentation mean? What change must starch and cane-sugar undergo before they ferment?

210. Is grape-sugar peculiar to the vine? What is a more correct term? Whence is it derived?

211. Can a solution of pure grape-sugar ferment? What then is necessary? Does sugar contain the elements of alcohol and carbonic acid? Which are they? Does sugar contain alcohol and carbonic acid? How much alcohol and carbonic acid could 100 parts of glucose produce?

212. Do solutions of pure sugar exist in nature? What do they contain within themselves?

213. What is a ferment? What elements more especially does a ferment contain? Is white of egg a ferment? What constitutes it one? What then is fermentation? From what Latin word derived?

214. What does grape-juice consist of? How is it that it ferments of itself?

215. What are the conditions favorable to the cultivation of the grape? How much wine is made annually in France? In Germany?

216. What change does the grape-juice undergo in fermentation? Is the air necessary to the process? What use may be made of the gas escaping? What salts are produced?

217. What is the chemical name for cream of tartar? How is it removed from good wine? Why is wine sour in bad seasons?

218. What acid salts do home-made wines contain? Why unwholesome?

219. How does a dry wine differ from a sweet one?

220. How are effervescing wines produced? What gas do they contain?

221. In what part of the grape does its color reside? Is this coloring matter soluble in water? In what medium then? How is red wine made?

222. How is the colour of dark sherry produced? Are wines ever adulterated? How is strength given? Acidity corrected? Astringency produced? Color conferred? How is bouquet imparted?

223. Does the quantity of alcohol vary much in wines? Give some instances.

224. To what does wine owe its intoxicating properties? How is pure alcohol obtained? What other name has it? What are its properties? Is it inflammable? When does it boil?

225. What substance does the formula  $C^4 H^5 O + HO$  express? How is it produced?

226. Has absolute alcohol much attraction for water? Is dilute alcohol poisonous? Can absolute alcohol kill?

227. Has alcohol ever been frozen? Is it adapted to the construction of thermometers? Why?

228. How much water does commercial spirit contain? Is alcohol as great a solvent as water? For what purposes is it employed?

229. How is ether made? How does it differ from alcohol? Can you give its formula?

230. What are the properties of ether? Its sp. gr.? Its boiling point? Why is it productive of cold? Is ether soluble in water? To what extent. Is not alcohol a greater solvent?

231. What compounds does ether so greatly resemble? What is it in consequence supposed to be? What is the compound called? How is it represented symbolically? What is a hydrate? What is alcohol a hydrate of?

232. What is the bouquet of wines due to? Whence the term?

233. What is Liebig's opinion of wine as a restorative?

234. Is much wine used on the Rhine? What diseases are almost unknown in consequence? Does the use of wine appear to do injury?

235. As an article of food, in what respect does alcohol stand high?

236. Which class eat most, teetotallers or wine-drinkers?

237. On occasion of a peace-meeting at Frankfort, what was the innkeeper's experience?

238. What fruits are employed in making cyder and perry? Describe the process? How is the rustiness produced? What becomes of the sugar of apples and pears? Are cyder and perry wholesome? Why not to all?

239. In the production of beer, whence is the sugar derived? Describe the malting process? What is diastase? What is it composed of? Does it exist in seeds and roots? What is the object of it?

240. What is the effect of malt upon starch? Give an illustration?

241. Describe the process of brewing? What does the brewer mean by the term wort? What is lupulin? Whence derived? How is the vinous fermentation induced? What gives rise to the froth from beer? How is the fermentation stopped?

242. Whence does porter derive its color? How much alcohol does it contain?

243. What is yeast? From whence is it derived? Does it increase in quantity? Is yeast a vegetable? What is the name of the plant? Does yeast contain nitrogen? How do you know it? What is the most remarkable property of yeast?

244. Does the manufacture of ardent spirits differ from that of beer. Describe the process? What is wash? How is whiskey made? From what source do highland whiskey and potteen obtain their flavor? What is rum? Whence does the name of brandy arise? How is it made? What spirits are prepared from barley? In what substance does rice abound? What is arrack?

245. How much alcohol is there in the chief spirits?

246. What effects have spirits upon the body?

247. May vinous fermentation be induced in milk?

248. What constituent of milk induces the so-called lactic acid fermentation? Mention some fermented roots in which lactic acid abounds? In what liquids may lactic acid be formed? Has the air anything to do with the process? What are the properties of lactic acid? Does it coagulate cold milk? What difference is there in the composition of lactic and lactic acid? What is the name of the salts of lactic acid?

249. Has the state of a ferment anything to do with the kind of fermentation? Give examples.

250. Has vinegar been long known?

251. Is it right to call the process a fermentation? Why not?

252. What kind of liquids produce vinegar? What change is accomplished?

253. Give some idea of the change which alcohol undergoes?

254. Can pure alcohol ferment? What is necessary?

255. How is the best vinegar made?

256. Describe the quick-vinegar process?

257. Whence do we in England obtain our supply of vinegar? How?

258. Do you know any other modes of making vinegar? To what is the flavor of wine-vinegar due?

259. Is there still another way? What is it called?

260. What is the chief adulteration of vinegar? How may taste, color, and smell be improved?

261. What is pure vinegar called?

262. What are the properties of pure acetic acid? What is its sp. gr.? Does it alter by distillation? What are acetates?

263. Is dilute acetic acid of common occurrence in nature? State what you know.

264. Is there any authority for using wine?

## CHAPTER V.

### CHEMISTRY OF THE DINNER-TABLE.

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265. Although WATER would be considered by some a very unsatisfactory accompaniment of the dinner-table, inasmuch as it is only second to air, and a positive essential in almost every purpose of domestic economy, it becomes necessary still further to consider some of its numerous qualifications.

266. Previous chapters have sufficiently explained the fact, that water never occurs in nature in a state of perfect purity, and this for the most obvious reasons. It is nature's great solvent. The rain as it falls, removes certain impurities from the air, and carries with it more especially those gases (such as ammonia and carbonic acid), which minister most to the wants of plants. For cooking and washing, it is impossible to have too soft a water; rain, with some qualification, is therefore, eminently adapted to both purposes. The mechanical impurities of rain are easily removed by filtration; animal and vegetable matter rendered harmless by boiling. With the exception only of great towns, where it is

usually very impure, boiled and filtered rain water answer every culinary purpose.

267. Clear water, although colorless in small quantities, is blue like the air when seen in mass. Clearness does not, however, prove the purity of the water; and it should be remembered that ordinary filtration can never remove dissolved impurities. Thus we should not rest contented with the water supplied to us by many companies, especially in London, and imagine, because we filter it, that it is therefore good and wholesome. Nor should we think, because a water wells up in outward purity, and is not conveyed through pipes, that it must therefore be good. On the contrary, every chemist gives it as his experience, that scarcely any well-water in a large town is fit to drink.

268. The qualifications of a good drinking water are peculiar: nature teaches us what these should be. If we examine carefully into the water contained in young vegetables, we shall find, that only a soft water, containing but small amounts of common salt, and salts of lime, potash, and magnesia, enter into their constitution: it is only when they become old, that the deposit in them of these salts (which correspond to the skeleton of the human and animal frame), increases. Again, if we examine carefully into such waters as are drunk readily by cattle, we find, that where they can choose for themselves, they will select that water, which, being otherwise clear, is soft, and but slightly curdles soap. For what is the object of the water we drink? Mainly to supply the drainage of the body. We

should cook our food with especial reference to its digestibility; or, in other words, its solubility. Now soft water is a much better solvent than hard water. For moistening our food, therefore, a soft water is preferable. As we eat more especially to supply the waste in our bodies, and when young, to increase their bulk; so we drink mainly to remove impurities from the blood. If we drink a very hard water, it not only lies heavily on the stomach, but has to be freed from some of the salts of lime, by distillation through the capillaries, before the blood can receive it: and then, from the quantity still contained, it ceases to be the great purifier which it is intended to be.

269. Water, to be good for drinking, should possess the following qualities:—Bright and clear as crystal, when poured into a tumbler, it should sparkle with the gases rising through. Both oxygen and carbonic acid gas, which communicate to water its refreshing and thirst-quenching properties, should be present, and for this reason, water should neither stand long in a warm room, nor in sun-light, nor be drawn long before it is wanted. It should possess no decided taste. Good water should but very slightly curdle soap, and should quickly form a lather with it. If a water can be obtained which cattle drink of readily, no hesitation need be felt about its quality.

270. With regard to the use of mineral waters, these are so variable in composition, that no general rule can be laid down. If a person is suffering from any disease in which there is a tendency to

deposit solid inorganic matters in any part of the body, such soft waters as those of Buxton and Malvern are to the purpose. If the body is broken down by excesses of any kind, the liberal employment of soft water, externally and internally, under proper medical superintendence, is recommended.

271. In health, only such mineral waters should be taken freely as abound in carbonic acid. Carrara water, and all kinds of soda-waters made with hard water, are to be condemned.

272. In disease, the mineral water employed, should abound in some one medicinal feature. Mineral waters are called *saline*, when common salt abounds: *magnesian*, when salts of magnesia give them their characteristic taste and properties; *chalybeate*, when carbonate of iron abounds; *hepatic* or *sulphurous*, when sulphuretted hydrogen is given off in appreciable quantity.

273. Any person with a tendency to become stout, should restrict himself in the use of water, beer, and, unless his system has been impaired, of all intoxicating liquors. The moderate use of wines, or malt liquor, at dinner, is only to be discouraged among the young, and the naturally intemperate. It must be an exceptional case when the digestive organs of a *growing* person require a stimulus, and none such should indulge in even small quantities of fermented liquors, except under medical advice. The use of weak table beer forms the only exception from this rule.

274. It is impossible to specify the exact circumstances, under which it may be beneficial to take a



moderate allowance of alcoholic stimulus, for the purpose of promoting either mental or bodily vigor. The Bible, in recommending wine as a gift of God, proves its capability of being put to legitimate uses. These uses are clearly legitimate, only so far as that they minister to health, energy, and virtue. Alcohol acts directly on the lining of the stomach, and its habitual employment, *in excess*, keeps this membrane in a state of irritation, amounting almost to inflammation: it destroys digestion and appetite, produces foetid breath, and incapacitates the drinker for mental exertion, induces sloth, a deadening of the moral faculties, premature disease, and death.

275. Of the quantity of water contained in vegetables, fruits, and meat, few are well-informed; and, as it would be impossible to speak of the *nutritive value* of the various kinds of food, without taking into account the water they contain, the subjoined Table has been drawn up, to show the proportion contained in the fruits, vegetables, &c., most in use :—

	Per cent. of Water.
Common mushrooms contain . . .	96·00
Cabbages . . . . .	92·00
Green-top turnips . . . . .	90·00
Carrots . . . . .	87·60
Beet-roots	} . . . . . 87·00
Champignons	
Milk	
Kohlrabi . . . . .	86·00
White Swede turnips . . . . .	85·00
Pears . . . . .	83·90

	Per cent. of Water.
Currants contain . . . . .	81·30
Peaches . . . . .	80·20
Parsnips . . . . .	72·40
Artichokes . . . . .	79·20
Flesh . . . . . from	76·0 to 79·00
Potatoes } . . . . .	75·00
Yams }	
Cherries . . . . .	74·90
Apricots . . . . .	74·40
Greengages . . . . .	71·00
Sweet potatoes . . . . .	59·00
Kidney-beans . . . . .	23·00
Haricots . . . . .	16·00
Beans . . . . .	14·50
Peas . . . . .	13·00
Rice . . . . .	12·50
Lentils . . . . .	12·00
Wheaten-flour . . . . .	10·00
Indian Corn or Maize . . . . .	6·00

276. It will be noticed from the above, that flesh (corresponding in composition to the flesh of our bodies), contains 79 per cent. of water; and the *quantity of water or beer drunk at the dinner-table, should correspond as nearly as possible with this proportion.* If our food be *dry*, the water drunk should be in quantity sufficient to bring the total amount up to 79 per cent.; if, on the contrary, water abound in our diet, then but little need be imbibed. We observe also, that the proportion of water in our kitchen vegetables, bears some relation

to the quantity contained in flesh; and that their value varies accordingly.

277. The greater part of our vegetables are either indigenous, or foreign : of the former, many of the present grow wild, such as asparagus; but, by continued cultivation, through a long series of years, they have produced numerous varieties. Of foreign vegetables, many have originally come from southern climates, chiefly from Italy; and the number of them has increased prodigiously in the course of the last two centuries. The kitchen gardens of England were, until about the end of the sixteenth century, as scantily supplied with vegetables, as the pleasure grounds were with shrubs and flowers. "It was not," says Hume, "till the end of the reign of Henry VIII., that any salads, artichokes, carrots, turnips, or other edible roots, were produced in England." The little of these vegetables that was used, was imported from Holland and Flanders, and Queen Catherine, when she wanted a salad, was obliged to despatch a messenger thither on purpose. The most important vegetable of the present day, the potato, was brought to England in 1586, by Sir Walter Raleigh; but its culture for the next century, must have been but partial, as the market price was then 1s. per lb. Broccoli and cauliflower were introduced from the Levant into Italy, about the end of the sixteenth century; and at the close of the seventeenth into England. The turnip was in cultivation in the sixteenth century; and it is stated, that when, in the years 1629 and 1630, there was a dearth in England, very good white bread was made

of boiled turnips, kneaded up with an equal quantity of wheaten flour.

278. Among the kitchen vegetables, of which uncertain traces are to be found in the works of the ancients, is *Spinage*. Its native country is unknown. The name *Spinargium* or *Spinachium*, first occurs in the year 1351, among the lists of food used by the monks on fast-days.—*Beckmann*.

279. The FRUITS used by our ancestors were neither numerous nor good. Gooseberries, strawberries and currants, indifferently good apples and pears, and decidedly bad plums and cherries, were about all. It should be remembered, that we owe many of our most familiar fruits to other countries, of some of which we have an intimation in their names.

280. *Cherries* were obtained from Cerasuntis, a city of Pontus, in Asia Minor. Lucullus, after the war with Mithridates, introduced them from Pontus into Italy; they were so pleasing as to be rapidly cultivated; and Pliny testifies that, twenty-six years afterwards, the cherry-tree passed over into Britain. The whole race of this tree was afterwards lost, and is said to have been restored by the gardener of Henry VIII., who brought it from Flanders. These facts may often be called to mind, for the cherry (*Prunus cerasus*, as botanists call it), is now one of our native trees, very common in woods; the wild fruit being well flavored, though there is but little pulp on the stone.

281. Another of our native wild trees is the *plum*, which has been so much improved by culti-

vation. There may be a doubt, indeed, whether the sloe is not the original stock, whence have been derived not only the several varieties of the plum, but even the peach, nectarine, and apricot. The *damson*, or damascene, was brought from Damascus.

282. The *strawberry* derives its name from the practice common to gardeners of laying straw under the plants as they come to maturity, to prevent the ripe berries from being soiled by the garden mould.

283. *Black* and *red currants* are natives of Britain; as are also *gooseberries*. Cold as some of the countries of Northern Europe are, large and beautiful berries may often be obtained. Even in the barren districts of Finland, and on the tops of Alpine mountains, where rocks appeared to be the only surface, cherries and gooseberries, with ruddy tints, have been met with. A traveller in Kamschatka found himself in a large forest, many of the trees being finely-grown, and amongst the underwood he perceived some bushes of large red berries, which, to his great astonishment, he discovered to be red currants, of a very large size and high flavor, but possessing a much more acid taste than those of our gardens.

284. With the *vine* mankind has, since the flood, been familiar. Ripe grapes are among the most palatable, wholesome, and nutritious of all fruits. The weight of grapes which every vine can properly produce is proportioned to the thickness of the stem immediately above ground. At Hampton Court there is a vine which yields about fourteen

hundred weight of very fine grapes. The grapes produced in Palestine are very large. The famous bunch of Eshcol, which required to be borne by two men, greatly surprised and pleased the Israelites, when they first beheld, in a barren and sandy desert, the fruits of the long-promised land they were to occupy. Even now, in the present neglected state of the country, some are still found to weigh twelve pounds.

285. The *pear* grows wild in our woods and copses, but it there yields fruit of a very inferior description, and very unlike the juicy produce of the orchard. From a deficiency of acid, this fruit is less wholesome for delicate stomachs than the apple; but to those of robust health it is both nutritious and excellent.

286. The *apple-tree* too is a native of Britain, being far from uncommon in woods and hedges, though the wild apples, or crabs, are small, dry, sour, and unpalatable, and would not be much improved by culture. By sowing and re-sowing the seed, and crossing and re-crossing the sorts thence produced, the thousand known varieties of apples are procured. The apple is both wholesome and nutritious. Heat, when applied in roasting, baking, or boiling, tends to break down the interstices of the cells of the apple, to diffuse the acid and the sugar more uniformly through the mass, to dissipate water, and to render the whole more easy of digestion.

287. STARCH is a most important ingredient both of all vegetables, of unripe fruit, of the crust of pie

and pudding, and of bread; it is also known to chemists under the various names of *amylum*, *fecula*, *amiline*, *amidine*. It is contained in the cells of vegetables, in the form of small white granules, which have no crystalline structure. These globules vary much in size and form, so much so indeed, that in the different species of vegetables they may be distinguished by a practised eye. A character, however, which is common to the majority of *feculae* (for thus are the granules technically distinguished), is a roundness of contour, when their particles have not been compressed by their contact in contiguous cells.



Fig. 18.

Microscopical as well as chemical researches show that starch is homogeneous (from *ὁμῶς*, homos, like, and *γένος*, genos, kind) in properties as in composition; and that its globules are composed of concentric layers, the external layers of which have exactly the same character as the internal. At page 92, among other properties of starch, its atomic constitution has been already noticed. In its greatest state of purity it may be said to consist of—

Carbon . . . . .	44·9
Hydrogen . . . . .	6·3
Oxygen . . . . .	48·8
	<hr/>
	100·0

Starch does not part easily from water, but retains it with considerable force; the quantity varying with the temperature at which the drying is accomplished. Thus, the starch of potatoes, which is moist and porous, even when subject to strong pressure, still retains 45 per cent. of water. That of the shops contains 18 per cent.

288. Plants vary very much, as to the quantity of starch contained in them, their bulbs and their seed. Thus we find in—

	Per cent. of Starch.
Rice flour . . . . .	85
Maize . . . . .	71
Wheat flour . . . . .	from 40 to 78
Barley . . . . .	from 40 to 50
Peas . . . . .	47
Haricots . . . . .	41
Lentils . . . . .	40
Potatoes . . . . .	from 12 to 23
Parsnips . . . . .	6

289. It is easy to understand why potatoes and rice should increase in bulk when boiled, when we reflect that the starch granules, in boiling, swell to about thirty times their original size.

290. Several varieties of starch are employed for making puddings, and other light dishes. In the Moluccas and Philippine Islands, grows a description of palm which yields a form of starch. When the pith of this palm is washed with water upon a fine sieve, a white powder is deposited by the milky liquid which passes through. This powder, when collected, forced through a metal sieve to granulate



or corn it, and dried by agitation over a fire, forms the genuine SAGO of commerce.

291. **ARROW-ROOT**, which derives its name from the root of the *Maranta arundinacea*, owing to its supposed efficacy in counteracting the effects of wounds caused by poisoned arrows, is extracted, by a mechanical process, from the roots, when about ten or twelve months old. In Bermuda, the roots are first deprived of their paper-like scales, and then ground by a kind of wheel-rasp. The pulp is thrown into clean water, and stirred about to separate the fibrous parts, which are collected in the hand. The milky liquor which remains is poured through a sieve, and afterwards allowed to settle for some time. The arrow-root sinks to the bottom, and when the water is poured off, the white pasty mass that remains is placed on clean white cloths to dry in the sun. It is then fit for use. When pure, it has a dull and opaque-white color, and crackles when pressed between the fingers. The process varies in Jamaica and at St. Vincent, but not materially. There are various kinds of spurious arrow-root in the market; many of the so-called "genuine" kinds are made from, or largely adulterated with, potato, and, although not unwholesome, are not nearly so nutritious as real arrow-root.

292. The *Manihot utilisima*, which is found in South America, has very large roots, rich in starch, from which **TAPIOCA** and **CASSAVA** are obtained. Tapioca differs from cassava only in being a purer kind of starch: the latter, however, is the more nutritious, because it contains a larger proportion of

nitrogenized constituents. Among the Indians, the cassava supplies the place of bread. The roots are scraped on a sort of rasp, formed of small fragments of flint stuck into a plank; the pulp is put to drain in a long strainer made of the entire bark of a species of fig; the juice having drained away, water is added to finish the washing; the liquid comes out nearly clear, and without bringing away any perceptible quantity of starch. To form the pulp into cakes of cassava, it is spread out on an earthen dish placed over the fire; the process being complete when the cassava is dry and slightly toasted on the outside. Cassava bread is not very palatable, but is frequently an indispensable article of provision with the South American traveller.

293. Arrow-root, sago, tapioca, and cassava, all contain ALBUMIN, in addition to starch, which, although in amount it never rises above  $3\frac{1}{2}$  per cent. is highly important. It has already been described at pp. 99 and 100. Starch, important as it is, would be a very unprofitable kind of food, were it not always associated with albumin, or a similar nitrogenized substance, which subserves the same purpose.

294. By the process of boiling, the starch-granules become simply, though greatly, expanded; arrow-root, for instance, in boiling water, quickly loses its whiteness and opacity, becomes transparent, and the whole of the water seems converted into a thick jelly-like mass.

295. In the baking of a sago or tapioca pudding, there is no doubt that a portion of the starch also

becomes converted into *dextrin*, as in the case of bread-baking. This substance, when pure, has the same specific gravity as starch, viz., 1.51. It has also the same composition, for we find in 100 parts of dextrin :—

Carbon . . . . .	44.3
Hydrogen . . . . .	6.0
Oxygen . . . . .	49.7
	<hr/>
	100.0

Its formula is therefore  $C^{12} H^{10} O^{10}$ . Owing to its solubility in water, dextrin is used in the arts as a substitute for gum; and it is this very solubility which renders cooked food, containing originally much starch, more digestible, as well as more palatable.

296. The use of milk, instead of water, in provisions where starch abounds, tends to render them more nutritious as well as more tasty; and is therefore to be commended.

297. Some vegetables—as, for instance, turnips and carrots—contain no starch, but a principle not unlike it. It is well known, that the juice of all fruits contains a gelatinous substance, to which many of them owe the property of forming jellies. This matter may be obtained by means of alcohol. If, into a quantity of currant-juice lately expressed, a portion of alcohol be poured, a gelatinous precipitate is formed after a certain time; this jelly, subjected to increasing pressure, and washed with dilute alcohol, gives the gelatinous principle in a pure state: this is PECTIN. Outwardly, it resembles

isinglass. Thrown into about one hundred times its weight of water, it swells considerably, and at length dissolves completely, giving rise to a stiff jelly. Pure pectin is tasteless, and does not affect the color of litmus. Potash or soda does not change it obviously; nevertheless, it is singularly modified under their influence, being changed into a peculiar body, having acid properties. PECTIC ACID has been found in every plant in which it has been sought for. It is contained in apples, pears, plums, cucumbers, &c.; in turnips and carrots, pectic acid amounts respectively to 2 and 5 per cent.

The composition of pectin and pectic acid is as follows :—

	Pectin.	Pectic Acid.
Carbon . . . .	42·9	42·8
Hydrogen . . . .	5·1	5·2
Oxygen . . . .	52·0	52·0
	<hr/>	<hr/>
	100·0	100·0

From this it will be seen that the elementary composition of both is identical.

298. SUGAR, too, is to be found in almost every part of vegetables. It is less abundant, however, in seeds, than in any other part. On account of its solubility in water, vegetables containing much of it, such as potatoes, turnips and carrots, should be steamed rather than boiled. Both cane-sugar and grape-sugar have been met with mixed in vegetables. It has been already pointed out how starch and cane-sugar may be converted into grape-sugar or glucose, but the inverse has not, *as yet*, been accomplished.

At no distant period, we may hope to see factories established in England for the preparation from potato-starch, of a cane-sugar which shall rival the best produce of the West Indies.

299. To the same class of ternary compounds, found in vegetables—that is to say, of such as consist of the three elements, carbon, hydrogen, and oxygen, to which starch, sugar, pectin, pectic acid, gum, and oil, belong—must be added WOODY FIBRE and CELLULAR TISSUE. Woody fibre consists, in fact, of two substances: one, the cellular substance constituting the tissue of wood, and of all the organs of plants; the other, the woody substance properly so called, filling, and in some sort consolidating, the cells. Cellular tissue is identical in composition with starch. Thus:—

	STARCH.	CELLULAR TISSUE OF	
		Apple.	Mushroom.
Carbon . . .	44·9	44·7	44·5
Hydrogen . .	6·3	6·1	6·7
Oxygen . . .	48·8	49·2	48·8
	<hr/>	<hr/>	<hr/>
	100·0	100·0	100·0

Now, the composition of woody fibre differs considerably from that of cellular tissue; it is richer in carbon. The elementary composition is:

Carbon . . . . .	53·8
Hydrogen . . . . .	6·0
Oxygen . . . . .	40·2
	<hr/>
	100·0

In the general acceptation of the term, the name of *wood* is applied to the solid part of the trunk and branches. It is heavier than water, and if it floats in this fluid, it is only because of the air with which its pores are filled. The composition of woody matter may be represented by carbon and the elements of water; of carbon the mean may be stated as 52, of hydrogen and oxygen, in the *proportions* which form water, at 48. The stringy substance in the stalks of cabbages, of old turnips, in kidney-beans, &c., contains it. It need scarcely be said that the production of insoluble, indigestible woody fibre, does not add to the value of an esculent, but rather detracts from it; besides the actual discomfort in eating a tough vegetable, its nutritive value is greatly reduced by old age.

300. We now understand better than formerly, the changes which the cells of vegetables experience as they grow, and become old. It is by the appearance of the encrusting woody matter, that their thin transparent, and, at first, colorless walls, thicken, become opaque, and acquire strength.

301. In the series of bodies, just considered, one only possesses the property of crystallizing, viz., sugar. But among ternary compounds met with in vegetables, and more especially in fruits, must be classed certain *acids*, most of which assume regular crystalline forms. Vegetable acids present all the general characters of mineral acids. Thus—they redden blue litmus paper, and form salts with metallic oxides, some of which, especially those of potash, soda, and ammonia, are soluble in water.

These acids, whether free or uncombined, are very frequently met with in fruit, sometimes in the leaves; more rarely in seeds and roots; but in combination with bases (oxides), they are met with in almost all parts of plants. They are very numerous; nevertheless, only a few of the most extensively distributed of these acids require description.

302. **OXALIC ACID** exists in a free state in the hairs of the chick pea: but it is met with more commonly in combination with potash and lime. The *binoxalate of potash*, a compound of two eqs. of oxalic acid with one of potash, is sometimes called salt of sorrel, from its occurrence in that plant. It is also found, associated with malic acid, in the wood sorrel (*oxalis acetosella*), and in garden rhubarb; hence their sour taste.

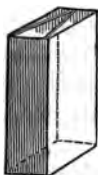


Fig. 19.

Oxalic acid separates from a hot watery solution, in colorless, transparent, oblique rhombic crystals, resembling Epsom salts. It tastes strongly acid, and is a deadly poison. (The proper antidote is chalk or magnesia, with either of which it forms an insoluble compound). When heated in sulphuric acid, it is entirely decomposed into water, carbonic acid, and carbonic oxide. The hydrated oxalic acid may indeed be said to consist of—

1 eq. of water . . . . .	HO
1 eq. of carbonic acid . . .	CO <sup>2</sup>
1 eq. of carbonic oxide . . .	CO

The formula of the hydrate is  $C^2 O^3 + HO$ ; its

symbol\* is  $\bar{O}$ . Its combinations are called *oxalates*.

303. TARTARIC ACID is always found naturally in combination with potash or lime. The grape, the tamarind, and the pine-apple, contain *bi-tartrate of potash*. It is also present, along with other acids, in the mulberry.

When new wine is set aside in casks, it gradually deposits a hard crust of *tartar*. This substance, when purified, constitutes the cream of tartar of the shops, which crystallizes in the same form as oxalic acid. It is soluble in 60 parts of cold water, but not in alcohol; hence, as the latter forms in wine, bi-tartrate of potash separates.

The tartaric acid of commerce is wholly prepared from this acid salt; its principal employment being in certain processes of the calico-printers. The pure acid forms colorless, transparent crystals of large size, which possess an agreeable acid taste. It dissolves readily in water, and causes a violent effervescence when mixed with a solution of carbonate of potash, or of soda; hence, it is extensively used in artificial effervescing draughts. The formula of crystallized tartaric acid is  $C^8 H^4 O^{10} + 2 HO$ ; its symbol is  $\bar{T}$ . *Tartrates* are salts of tartaric acid.

304. CITRIC ACID gives sourness to the lemon, lime, orange, cranberry, and the red whortle-berry. Mixed with much malic acid, it is found in currants, cherries, gooseberries, raspberries, strawberries, and the common whortleberry. It forms transparent,

\* The horizontal line placed over the initial letter, indicates an organic acid.



colorless crystals, possessed of an agreeable acid taste; effervesces like tartaric acid with carbonate of soda, and like it, being without injurious action upon the system, is much employed for effervescing draughts. The formula of citric acid is  $C^{12} H^5 O^{11} + 3 HO$ ; its symbol is  $\overline{C}$ . The citron has lent its name to the acid.

In combination with lime, citric acid exists in the tubers, and with potash in the roots of the Jerusalem artichoke. Such combinations are called *citrates*.

305. MALIC ACID is the acid of apples and pears; and along with citric acid, it occurs in many fruits. It is found abundantly in unripe apples, hence its name, from *prunus malus*, the botanical name of the apple tree. Malic acid is, moreover, the chief cause of the sour taste of the plum, the sloe, the elderberry, the barberry, the fruit of the mountain ash, and rhubarb.

Malic acid is a crystalline solid, very soluble in water. It has an agreeable sour taste; becomes mouldy, and spoils by keeping. The formula of malic acid is  $C^8 H^4 O^8 + 2 HO$ ; its symbol is  $\overline{M}$ . The salts are called *malates*.

306. Valuable as are these binary and ternary compounds as articles of food, they cease to be so when unassociated with nitrogenized substances. Nature points this out most distinctly. In milk, which is the most perfect form of animal food, we have the various constituents according to their greater or less importance. The binary compound, water, amounting to no less than 87 per cent., holds in solution about 8 per cent. of such ternary compounds

as butter and sugar, and above 4 per cent. of the quaternary compound, casein. Every variety of flour contains albumin and gluten, in addition to starch. Thus we perceive the importance of quaternary compounds in the different vegetables and other kinds of food: how necessary, therefore, to understand their nature and properties.

307. **VEGETABLE ALBUMIN** and **GLUTIN** are not the only nitrogenized constituents of vegetable food.

308. Gluten itself is a mixture of several nitrogenized substances, but more especially of gliadin and **FIBRIN**. This vegetable fibrin consists of unadhesive separate filaments, and whether derived from wheat, barley, or oats, has exactly the same composition as albumin.

309. Still more carefully examined, wheaten-flour is found to contain another quaternary compound, **CASEIN**, so called from the resemblance it bears to the casein of milk.

310. To these must be added **LEGUMIN**, which abounds in many seeds used as vegetables, especially in such as are included in the natural family, *leguminosæ*, to which peas and beans belong. By many chemists it is considered analogous with casein. Legumin is very soluble in cold water, and has a lustrous white appearance. On boiling a solution of it in water, it coagulates and falls in flakes like white of egg. The solidity of almonds, hazelnuts, of the kernels of stone-fruit, of peas, lentils, and beans, is due to its presence.

311. Analysis indicates a very great similarity in composition between legumin and the four other

quaternary compounds separable from wheat-flour. The following shows the composition of them :—

	Carbon.	Hydrogen.	Nitrogen.	Oxygen.
Legumin . . .	50·5	6·9	18·2	24·4
Fibrin . . .	53·2	7·0	16·4	23·4
Albumin . . .	53·7	7·1	15·7	20·5
Casein . . .	53·5	7·1	16·0	23·4
Glutin . . .	53·3	7·2	15·9	23·6

312. These nitrogenized substances, differing but little from one another, are those which are now recognised as distributed through the whole body of every vegetable. Now, as the value of esculents must in some measure depend upon the presence of one or more of these compounds, similar information is subjoined on this head to what has been already given with reference to the quantity of water and starch found in them. The per-centage value of grains, seeds, roots, and vegetables, as regards the quantity of nitrogenized or nutritive constituents, is as follows ;—

		Nutritive constituents.
Wheaten Flour contains from 12 to 35 per cent.		
Dried Peas	contain . . . .	29 „
Kidney Beans	„ from 24 to 28	„
Green Peas	„ . . . .	24 „
Lentils	„ . . . .	22 „
Haricots	„ . . . .	22 „
Maize	„ . . . .	12 „
Rice	„ . . . .	7 „
Yams	„ . . . .	3 „
Mushrooms	„ . . . .	2·9 „
Swede turnips	„ . . . .	2·8 „

		Nutritive constituents.
Sweet potatoes	contain . . .	2·6 „
Cabbages	„ . . .	2·5 „
Parsnips	„ . . .	2·1 „
Beetroots	„ . . .	2 „
Potatoes	„ . . .	2 „
Kohlrabi	„ . . .	1·5 „
Turnips	„ . . .	1·5 „
Carrots	„ . . .	1·5 „

313. All quaternary compounds contain further above one per cent. of sulphur and phosphorus, with the exception only of casein, which contains no phosphorus. The composition of animal albumin has already been given at p. 99. Vegetable albumin contains the same elements in the same proportions.

314. SULPHUR is an *element* of great importance; it exists in many oils, and very largely in oil of onions and garlic. It will be remembered also as a constituent of oil of eggs; likewise of mustard and cress. Sicily furnishes a large proportion of it for European consumption. When pure, it is a pale yellow, brittle solid. Its specific gravity is 1·98.

Sometimes it is found beautifully crystallized in form of acute octahedrons. (Fig. 20). It melts when heated, and sublimes\* unaltered, if air be excluded. Sulphur or brimstone is largely used in the manufacture of sulphuric acid (oil of vitriol) and of lucifer-matches. In its chemical relations, it bears great resemblance to oxygen, and



Fig. 20.

\* Sublimation is a species of distillation, but the product of evaporation is always solid.

forms *sulphides* corresponding in composition with oxides. Its combining proportion is 16 : its symbol S.

315. The PHOSPHORUS of albumin is obtained by plants from the soil. Not that it is ever contained in the ground in an uncombined form, but in chemical combination with oxygen and lime, as phosphate of lime or bone-earth. This phosphate passes into the organism of plants, and ultimately into the bodies of human beings or animals, to which these latter serve for food. By a chemical decomposition, the nature of which it is not easy to explain, the more highly organized parts of plants extract their phosphorus. This element is always obtained from burnt bones. When pure, phosphorus very much resembles wax, and is soft and flexible. Its specific gravity is 1.77. It melts at the low temperature of 108°, and boils at 550°. Its equivalent is 16: symbol P. It is not soluble in water, and is usually kept immersed in that liquid, on account of its easy inflammability. It sometimes takes fire by the heat of the hand, and demands great care in its management; a blow or hard rub will kindle it. A stick of phosphorus held in the air always appears to emit a whitish smoke, which in the dark is luminous. To this property it owes its name, *φωσφόρος*, phosphoros\* (from *φῶς*, phos, light, and *φέρειν*, pherein, to carry). The luminous appearance of the sea at night, when disturbed by a ship moving through it, is owing to

\* The consumption of phosphorus for the apparently trifling article of lucifer-matches is something prodigious.

the presence of myriads of small marine animals, of various kinds, which possess the power of emitting the peculiar light, called, from its supposed origin, phosphorescent. The light of the glow-worm, the lantern-fly, and other insects, is attributed to the same cause; and every one knows that most fish, and molluscos animals, such as crabs and lobsters, when in a state approaching to, or of actual decomposition, give out the same kind of light.

316. When phosphorus is set on fire in air, it burns with a bright flame, generating a snow-like, caustic vapor. This is PHOSPHORIC ACID, formed by the union of phosphorus with the oxygen of the air. It is composed of one equivalent of phosphorus with five of oxygen; its formula is therefore  $PO_5$ . Phosphoric acid has great affinity for water, with which it combines, forming three distinct compounds. It is a very powerful acid; its solution in water has an intensely sour taste, and reddens litmus paper. Its combinations are called *phosphates*. Very few bodies present a greater degree of interest than this substance.

317. But to return more immediately to the general subject: the vegetable food of man always contains nitrogen, in one or other of the above-named forms. Its nutritive properties increase in the precise ratio of their presence; or, in other words, the value of different kinds of food is in proportion to the quantity of *nitrogen* contained in them. The experiments of Magendie have shown that substances, such as sugar and starch, which contain no

azote, will not support life; and, on the other hand, it is ascertained that the quality of flour, for example, improves as the amount of gluten which it contains increases. We therefore conclude, that the azotized principles of vegetables are essential; and that they are of themselves insufficient for the nourishment of animal life, except when accompanied by starch, gum, bone-earth, and other matters which concur in nutrition.

318. Men and animals, then, find the several substances which make up their bodies ready formed in the food they consume: in this respect they differ materially from plants. A vegetable may be defined to be an organized being, which derives its food from gases and the soil; while an animal exists by incorporating into itself, from foreign sources, matter similar to that of which its own substance is composed.

319. The constituents of *meat* are, as far as regards their nutritive properties, very similar to those of vegetables. Animal fibrin, albumin, and casein, have their counterparts in vegetables: the history of animal albumin is that of vegetable albumin.

320. Food from without can only be made available for the support of life by being first converted into BLOOD, and it is the material from which all the secretions are derived. The blood in vertebrated animals has a red color, and a temperature above that of the medium in which the creature lives. In its ordinary state it has a slimy feel, a density of 1.053, a peculiar odor, and an alka-

line\* reaction, from the presence of an alkaline phosphate of soda.

321. To the naked eye, blood, like milk, appears a homogeneous fluid; but it is not so in reality. When examined by a good microscope, it is seen to consist of a transparent, pale, straw-colored liquid, in which countless little red discs float: besides these, other and less numerous, but larger bodies are observed, of a roundish but less regular form, called white corpuscles or lymph-globules.

322. When blood is left to itself, it soon coagulates and forms a clot, which gradually contracts, and then floats in a clear liquid.

323. The SERUM of blood is the clear pale fluid part, and may be said to be an alkaline solution of albumin in water.

324. The CLOT or CRASSAMENTUM, is a mechanical mixture of FIBRIN and the COLORING PRINCIPLE swollen and distended with *serum*. In the blood we have an instance of fibrin in a soluble state. Its character may be best studied by agitating fresh-drawn blood with a bundle of twigs, when the fibrin attaches itself to the latter in form of long, white, elastic threads or fibres, which, under the microscope, appear to consist of small globules arranged

\* The word alkaline is of Arabic origin, and is derived from *kali*, the name of a vegetable species from which soda was formerly extracted: the Arabic article of perfection, *al*, expresses the superiority of the alkali over the plant which afforded it. An alkali blues reddened litmus paper.



in strings. It is quite tasteless, and insoluble in both hot and cold water. The color of the clot is owing to a compound called HÆMATOSIN; it contains albumin and globulin, and coagulates by heat. No method having as yet been discovered to separate globulin and albumin, hæmatosin in a pure state has not yet been described. It communicates to water a splendid crimson color, and differs from the other animal principles in containing oxide of iron to the extent of 7 per cent.

325. If blood be evaporated to dryness, and exposed for some time to a red-heat in the air, it will burn away, with the exception of a small amount of ASH. This consists of alkaline phosphate of soda, phosphates of lime and magnesia, phosphate of iron, common salt, and sulphates of potash and soda; of the same constituents, in fact, which we find in the ashes of our principal articles of food (eggs, milk, bread and meat, &c.). We find these ashes more or less abundant in vegetables, according to their power of supporting nutrition. Thus, they abound in the seeds of our corn and leguminous plants; for example, in wheat and peas.

326. Muscular tissue, muscular fibre, or meat, is composed chiefly of fibrin; mixed, however, in the ordinary state, with blood, membranes, nerves, fat, &c. A thin slice of lean meat, washed in cold water until perfectly white, affords an excellent example of fibrin in its insoluble form. Now, the basis of all meats, whether fish, flesh, or fowl, is the same. If an extract be made of finely minced meat with

water, a reddish-colored fluid is obtained, having the taste peculiar to the blood of the different classes of animals. When heated to  $150^{\circ}$ , the albumin which it contains coagulates, while the color remains; but if the heat be continued, the fibrin, together with the coloring matters and cellular tissue, separates, and a clear liquid is obtained. This *broth* will be found to be distinctly acid. The acidity of the juice of flesh depends upon the presence of free lactic and phosphoric acids. If one or other of these acids were removed, meat would be found to possess an alkaline reaction, for the blood has always such; indeed, all the conditions of an electrical current are present in the living organism. The blood-vessels and lymphatics contain an alkaline fluid, while the surrounding fluid (that of the flesh) is acid; the tissues of which the vessels are composed being permeable for one or other of these fluids. It is, therefore, very probable, says Liebig, that an electrical current takes a share in the vital processes, though very little is known about it.

327. The chemistry of flesh demonstrates that, according to the duration of boiling, a more or less complete separation of its soluble constituents takes place. Since flesh taken as food is again to become flesh in the body, it should, as far as possible, contain all the original constituents of the raw meat. The meat without the broth is so much the less adapted for nutrition, as the quantity of water in which it has been boiled is greater; if meat be extracted with cold water, all the sapid and odorous principles are, together with the albumin, transferred

to it. The smell and taste of *roast* meat arise from the soluble constituents of the juice, which have undergone a slight change under the influence of a higher temperature. Meat which has been rendered quite tasteless by boiling with water, acquires the taste and peculiarities of roasted flesh, when moistened and warmed with a cold water infusion of raw meat which has been evaporated till it has acquired a dark brown color. From all the different kinds of flesh we obtain, by the aid of cold water, the whole of the albumin present in them, in a soluble form. Muscular fibre is everywhere surrounded by a liquid containing it, and the *tenderness* of meat is dependent upon the quantity present. In young animals the quantity of albumin is great; in old ones it is small.

328. Now, when meat is to be eaten, the albumin should be retained in it; for not only does it preserve the fibrin from becoming hard, but it gives to it softness and delicacy. The influence of boiling water upon albumin is well known. The best method of boiling meat intended for food is to introduce it into *boiling water*; if the boiling be kept up for five minutes, and then so much cold water be added as to reduce the temperature to  $165^{\circ}$ , and the whole kept at this temperature for some hours, all the conditions are united which give to the flesh the quality best adapted for its use as food. When it is introduced into the boiling water, the albumin immediately coagulates from the surface inwards, and in this state forms a crust, which no longer permits the external water to penetrate into the

interior of the mass of flesh. But the temperature is gradually transmitted to the interior, and there effects the conversion of the raw flesh into the state of boiled. The flesh retains its juiciness, and is quite as agreeable to the taste as it can be made by roasting. When the temperature of the interior of a piece of meat has not reached  $144^{\circ}$ , it presents a blood-colored or *underdone* appearance.

329. The flesh of *poultry* is sooner done than meat, because it contains little blood, and therefore requires a lower temperature.

330. The use of *lard* in roasting is to prevent the extraction of the *tasty* constituents from the flesh by the escape of its juices, and the evaporation of the water, which causes hardening.

331. Now, although the introduction of the raw meat into boiling water is the best process for *dressing* it, it is the worst for obtaining *soup*. If the raw meat be placed in *cold* water, and this brought very gradually to the boiling point, there occurs, from the first moment, an interchange between the juices of the flesh and the external water. The flesh loses, while the soup gains in *sapid* principles, and extracts both lactic and phosphoric acids,—two most important constituents of the gastric juice. The best method of preparing so-called *beef-tea*, is to take finely-chopped raw beef, to mix it with its own weight of cold water, and, after the lapse of about ten minutes or more\*, to

\* The time must depend upon the state of the chopped beef; if it is not very fine, an hour is not too much for soaking.

heat it slowly to boiling. It should be allowed to boil for two or three minutes, and should then be strained through a cloth; when an equal weight of the most delicious and strong beef tea (such as cannot be obtained by boiling for many hours) is at once obtained. When properly seasoned, it forms the very best soup that can be made.

332. It has long been customary to ascribe to the gelatinous matter dissolved during boiling, which gives to concentrated soup the property of forming a jelly, the chief properties or peculiarities of the soup; but Liebig has shown this to be a mistaken notion. The simplest experiments prove that the amount of dissolved gelatin in well-prepared soup is so small, that it cannot come into calculation in explaining its nutritive properties. GELATIN (isinglass is pure, glue impure gelatin) is, in itself, quite tasteless, and consequently the taste of the soup cannot be derived from it. Boiling water, when allowed to act for five hours on finely-chopped flesh, does not dissolve more than the fifth part of the matter soluble in cold water, even after the albumen has been separated by heating the cold infusion; and this fifth part, besides, does not consist of pure gelatin, but contains all the products dissolved out of the muscular fibre by long boiling.

333. It is equally customary to ascribe great strength to dark-coloured soups. A little burnt sugar (caramel) or burnt onion, will give depth of color to the beef-tea prepared after the above prescription.

334. *Salted meat* is deficient in nutritive and di-

gestive properties, and should never be eaten by a dyspeptic person. In the process of salting flesh, the acids, much of the albumin, and other matters, are removed in the brine; it is therefore obvious, that as the juice of flesh is not very dissimilar to the gastric juice, its removal must render the meat less nutritious. It is probable, that if, before salting, the meat were plunged for three minutes into boiling water, it would not lose so much of its goodness. The practice of using salt meat at infirmaries is highly objectionable. The object—viz., that of making it keep in warm weather—may, perhaps, be effected by plunging the fresh meat into slightly-salted boiling water, and re-heating till the water again boils.

335. Fully to explain the nature and uses of COMMON SALT, would occupy too much space; its importance will be clearly perceived in the record of the fact, that more than one-half of the total weight of the ashes of blood consists of salt. It has become a necessary even for the rudest nations; in not a few countries it is the most valuable mercantile commodity. Of the various kinds of vegetable food, seeds contain the smallest amount of it; green vegetables the largest proportion. Those which consist most largely of starch, such as potatoes and rice, require most salt to render them palatable. Moreover, when we consider that one of the constituents of salt (soda) is essential to the formation of bile, and that the free acid contained in the gastric juice is hydrochloric acid, and derived from salt;—all these facts, taken together, seem entitled to be considered as proofs of the

necessity of the presence of salt for the vital process, and of the addition of salt to the food of men.

The earth, the sea, and spring-waters, abound in salt or CHLORIDE OF SODIUM. In some places it is found in the interior of the earth, in immense beds, from which it is broken up and dug out. It looks like a stone, and is therefore called *rock-salt*. In those places where the rock-salt is mixed with stones and earth, a hole is bored in the middle of the bed, and water let into it. The water is pumped up again as soon as it has become saturated\* with the salt, and is again expelled by evaporation. In the so-called natural brine springs, salt is found in solution, and also obtained by evaporation. In hot countries, salt is prepared from sea-water, which is evaporated in shallow tanks by the heat of the sun. It is called *bay-salt*, and has a bitterish taste, owing to the presence of salts of magnesia. A pound of sea-water contains about half an ounce of salt.



Fig. 22.

Salt crystallizes in CUBES (fig. 22), and is as soluble in cold water as in hot. When thrown into the fire, it *crackles* briskly, or *decrepitates* (*de*, from; and *cre-pitare*, to crackle). This proceeds from a trace of water which remains in the crevices of the crys-

\* When a liquid has dissolved as much of a substance as it can hold, it is said to be saturated. The term, of course, is limited by temperature, as hot solutions usually take up more than cold.

tals; which, on being heated, expands and bursts them asunder.

Chloride of sodium or salt, is a chemical compound of the two elements, CHLORINE and SODIUM. One of its constituents, CHLORINE, is the greatest bleaching agent, and disinfectant, we are acquainted with. It is a yellow gaseous body, of intolerably suffocating properties, producing a very violent cough, even when inhaled to an exceedingly small extent. Its name is derived from the color of the gas; *χλωρος*, chloros, signifying yellowish-green. Its specific gravity is 2.5; its equivalent 36. Symbol Cl.

336. HYDROCHLORIC ACID,—a constituent of the gastric juice,—is a compound of one atom of hydrogen with one of chlorine; its symbol is therefore HCl. The strongest liquid acid of commerce, or spirits of salt, is a solution of 418 volumes of hydrochloric acid gas in one volume of water.

337. SODIUM, the other component of salt, is a silver-white metal, lighter than water, and possessed of the remarkable property of burning with flame when thrown upon hot water. The latter is thereby decomposed; its oxygen unites with the sodium, forming soda, whilst its hydrogen is set free. The equivalent of sodium is 24, and its symbol (Natrium) Na.

338. These two extraordinary substances in chemical combination, form that most useful and abundant substance, common salt, which is expressed symbolically by Na Cl. Without it, no complete digestion can take place. The deficiency in nutri-



tive properties, which is the characteristic of salt meat, is then due,—not to the presence of an excess of salt, but to the fact that the salt has removed the juices of the flesh, which are so essential in digestion.

339. Nor are all kinds of flesh of equal value. Veal, for example, is totally different from beef, the inorganic parts or ashes of which latter are much richer in alkalies.\* It also contains more gelatin and less fat than beef. Further than this, it is essentially distinguished from beef, by its containing  $\frac{2}{3}$  less IRON. Now, iron, in the state of OXIDE, is, without doubt, one of the chief constituents of the blood. A strong diet must therefore contain a certain amount of iron; for it is quite certain, that if excluded from the food, life cannot be supported.

340. Vegetable food, which includes, of course, bread, contains as much iron as beef, or red meat generally.

341. *Fish* contains even less iron than veal; its other constituents are the same as those of beef. When fish is boiled, a part of the soluble ingredients is taken up by the water, and the nutritive value, consequently, diminished.

342. The advantage of *stewing* over boiling, depends on the fact, that in the former process all the soluble matter is retained in the sauce or juice, which is served with the meat.†

343. Taste being the best test of good cookery, it

\* Potash and soda are alkalies.

† For further information, see Liebig on Food, from which work all the information on flesh here given is taken.

is obviously of the highest importance, in the process of cooking, to retain, as far as possible, the sapid principles of vegetables, as well as of meats. The practice of boiling meat or vegetables with large quantities of water, which is thrown away, and with it the whole, or nearly the whole, of the soluble matter, is clearly objectionable. The process of *steaming* is, in most cases, far preferable to boiling. Potatoes should always be boiled in their skins, for these keep in much that is valuable. Baked or roasted potatoes are, however, most wholesome; and this is owing partly to the removal of water, and partly to the change which the starch undergoes.

344. We must not altogether overlook so important an element of dinner as CHEESE. It is a constituent of milk. When milk, freed from cream, is heated to 150°, or thereabout, and mixed with a little rennet, (an infusion of the stomach of the calf in water,) it in a short time coagulates, and gradually separates into a solid white matter, called *curd*, and a liquid portion distinguished by the name of *whey*. Pure casein is tasteless, and almost insoluble in water. According to Mulder, it contains in 100 parts :—

Carbon . . . . .	53·83
Hydrogen . . . . .	7·15
Nitrogen . . . . .	15·65
Oxygen } . . . . .	23·37
Sulphur }	
	<hr/>
	100·00

The sulphur in it, amounts to 1 per cent.

Cheese is coagulated casein, subjected to pressure for the purpose of freeing it from the whey. But if cheese consisted only of casein, it would be hard, horny, and utterly tasteless. Good cheese is, however, always made from milk still retaining its cream or butter, which separates along with the casein; and in Stilton, which is one of the richest cheeses, the milk is not only allowed to retain its natural quantity of cream, but an additional quantity is added. The fresh cheese being kept constantly cool and dry, undergoes a peculiar kind of putrefactive fermentation, (the details of which are very little understood), by which principles are generated which communicate to it a peculiar taste and odor.

*Cheese*, then, is a mixture of *casein*, with *butter*, and about 6 per cent. of phosphate of lime, or bone-earth. The difficult digestibility of cheese, as compared with meat, is no doubt owing to its composition. Not only is it insoluble in water, but it brings with it little that aids digestion. The use of a morsel of decaying cheese as a relish, is no doubt an aid to digestion, for it acts as a solvent upon the food in the stomach; that is to say, in the same way as does a ferment.

345. Bone-earth and bones should be carefully distinguished from one another. Every species of vegetable and animal food which contains albumin, or any one of the quaternary compounds, contains phosphate of lime, or the earthy, incombustible, inorganic ingredient of bones. Thus in the former paragraph, cheese has been said to contain 6 per

cent. of phosphate of lime or bone-earth, because phosphate of lime is its chief component. As its name denotes, it is a compound of phosphoric acid with lime. But, to speak more correctly, bone-earth is a compound of phosphate of lime, with more or less of phosphate of magnesia and carbonate of lime.

346. The bones themselves consist of a living or organic portion, formed of cartilage; and an earthy inorganic portion. The amount of each varies, according to the nature of the animal, and its age. According to an analysis made by Berzelius, the bone of an ox consists of:

Cartilage . . . . .	33·30
Phosphate of lime . . . . .	57·35
Carbonate of lime . . . . .	3·85
Phosphate of magnesia . . . . .	2·05
Soda, with a little common salt . . . . .	3·45

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100·00

347. The longer cylindrical bones, such as those of the extremities, are hollow, and generally filled with *marrow*. In composition, it is analogous to those fats in which olein and margarin are predominant constituents.

348. In the third chapter of this work, at p. 81, allusion has been made to Liebig's division of all classes of food, into such as keep up the animal heat, and such as restore the waste of the flesh. There ought to be a definite relation between the amount of nitrogenous or nutritive matter taken

into the system, and that of the starchy or calorifiant (heat-producing); hence a proper *diet* must consist of that in which the nutritive matter is duly proportioned to the calorifiant.

349. By a fit admixture, a diet can be obtained of a composition, analogous to that of milk or of wheaten bread. By the addition of bacon or fat pork to peas and beans; of fat bacon to veal; of potatoes to beef; of rice to mutton; we increase in each case the proportions of heat-giving matter. The same result, though to a much smaller and less useful extent, is obtained by the use of fermented liquors, which, when taken with lean flesh and little bread, yield a diet approaching to milk.

350. We know that when food is withheld, the body loses weight; that, by the food, the weight of the body, and the power of producing new manifestations of force, is restored. In a state of rest, man requires less food than when in active exertion. It is, therefore, not a matter of indifference what is the quality of the food which he must daily consume, in order to recover his original power, and to perform on the following day, an amount of work equal to that of the previous one.

351. In a healthy adult, whose weight should not be perceptibly altered from year to year, the proportion of the parts, and their composition, are the same as at the beginning of the period. The whole quantity of the food taken in the course of the year, has not been employed in increasing the weight of the body, but in repairing the waste produced by exertion. For every movement of the

limbs, every glance of the eye, every thought that crosses the mind, is accompanied by the transformation of a certain amount of nitrogenous matter into a soluble form, to be ultimately expelled from the system.

352. To preserve the body in a healthy condition, the quantity of food taken at meals should be in proportion to *age* and the amount of *exercise*. A person who takes much active exercise in the open air, or whose work is such as to give vigorous employment to the muscles, will be able to eat double the quantity that would be good for one who leads a sedentary life. The state of the weather, too, has much to do with the quantity, for the colder it is, the more food is necessary. The Esquimaux will devour as much as twelve pounds of raw whale's blubber in a day; whilst the inhabitants of hot climates live on a very spare diet. In the case of healthy vigorous men, Liebig calculates that as much as 14 ounces of carbon are exhaled every 24 hours from the lungs, in the form of carbonic acid. The colder the air, the larger is the amount of oxygen we take into the lungs at every breath: for by cold the air is condensed; and though the relative proportions of oxygen and nitrogen in air are the same both in winter and summer, the actual amount of oxygen inhaled must be greater than in summer. And so, inasmuch as substances which abound in carbon and hydrogen are the heat-sustaining principles of the body, our food in winter ought to contain more of these than in summer. All inhabitants of very cold climates live by hunting, an exertion

which quickens and deepens the breathing: a greater weight of oxygen is thus taken into the lungs, and absorbed by the blood at each inspiration. The exhaled air will be laden with watery vapor and carbonic acid, and the temperature of the body will be kept up in spite of the piercing external cold.

353. It should, therefore, be borne in mind, that we are by no means to eat a certain quantity of food merely from custom. The food that is required, and hence the appetite, must be proportional to the amount of carbon required to supply the animal heat. Now, in hot climates, where the external cooling is less, less heat is required, the appetite is weaker, and the usual food, consisting of fruits and vegetables, contains a far smaller amount of carbon than in cold climates, where the appetite is keen, and the food, such as flesh, or even blubber, highly carbonized. For the same reasons, warm clothing, which diminishes the loss of heat by external cooling, blunts the appetite; and those who remove from a cold to a warm climate, always find that their appetite falls. This is a warning from nature to diminish the amount of food taken; and if it were attended to, and the common but absurd practice of stimulating the appetite by ardent liquors, hot spices, and pickles, abandoned, Europeans might enjoy better health in the Indies than they usually do.

354. It is further, very important to avoid *over-drinking* at meals; large draughts of water or beer chill and disorder the stomach, rendering it unfit to perform the functions of digestion. It should be remembered, that the quenching of thirst does not

and upon the quantity of liquid imbibed; and, in general, about half a pint of fluid, whether it be in the form of water, beer, coffee, tea, or a, drunk in small quantities at a time, will suffice each meal.



## QUESTIONS ON CHAPTER V.

265. Why is it necessary further to consider some of the properties of water?

266. Why does water never appear in nature in a state of complete purity? What impurities does rain remove from air? Why is rain well-adapted to washing? What impurities may be removed from it by filtration?

267. Is clear water of necessity pure water? Is well-water in towns usually fit to drink? What impurities are removable from water by filtration?

268. What are the qualifications of a good drinking water? What waters do cattle select when they have the choice? What is the object of water?

269. Describe a good water? Why should drinking-water not stand in the sun?

270. Why can no rule be laid down as to the use of mineral water?

271. What mineral waters may be used in health?

272. What do we understand by a saline water? What are magnesian waters, chalybeates, hepatic waters?

273. Should a stout person drink much of any liquid?

274. What is the effect of alcohol upon the stomach?

275. Has the nutritive value of food any necessary connection with the quantity of water contained in vegetables? State the quantity of water in a few of the leading fruits and vegetables?

276. How much water does meat contain? Should the water we drink bear any such proportion?

277. Whence have our vegetables been chiefly imported? Do any of them grow wild? Has cultivation altered them much? When were carrots and turnips introduced? To what place did Queen Catherine send for a salad? In what year was the potato brought to England? Who brought it? Broccoli and cauliflowers, when were they first introduced?

278. When do we first read of spinage? What people were in the habit of eating it?

279. What character did the fruits used by our ancestors bear? Are any of their names indicative of the countries from which they were brought? Give an instance?

280. About what time was the cherry first cultivated in England? When was its cultivation restored? Does the cherry grow wild?

281. What is the origin of the plum, and the supposed origin of the peach, nectarine, and apricot? From what country was the damson brought?

282. Whence does the strawberry derive its name?

283. Of what country are currants natives? Have they been found in the north of Europe? Relate what you know?

284. Has the vine been long known? Is it a wholesome fruit? How many hundred-weight of grapes has the Hampton vine been known to bear? What do you know of the Eshcol grape?

285. Does the pear grow wild in England? Why is the pear a less wholesome fruit than the apple?

286. What country is the apple a native of? How have the varieties now known been obtained? How many varieties are there supposed to be? What effect has cooking upon the apple?

287. What is the most important ingredient of vegetables? Under what various names is the substance known? In what form is it contained in the cells of vegetables? Is it possible to distinguish the vegetable from the form of the starch granule? What is the word homogeneous derived from? What per-centage of carbon does starch contain? Does it contain nitrogen? What, then, are its other constituents? Has it any great power of retaining water? Does the starch of the shops contain much?

288. How much starch is contained in rice? How much in potatoes and peas?

289. Why do rice and potatoes swell in boiling?

290. Are any varieties of starch used in making puddings? Name them. How is sago prepared? What kind of tree is it obtained from?

291. From what property does arrowroot derive its name?

What is its botanical name? How is it prepared? What appearance does it present when pure? With what root is it frequently adulterated?

292. What is the name of the plant from which tapioca is derived? In what respect does it differ from cassava? Relate the manner in which the Indians prepare cassava bread?

293. What substance do these various forms of starch contain? What do you know of its properties? Is it essential? What is its per-centage in cassava?

294. What change does arrowroot undergo in boiling?

295. Into what new substance is starch changed when strongly heated? Does it differ from starch in composition? How does it differ in property? Is it used in the arts?

296. What is the use of milk in cooking provisions in which starch abounds?

297. What is the name of the principle contained in turnips and carrots? To what principle is the jelly in fruits due? How may it be obtained from currants? What substance does pectin resemble? Is pectin contained in carrots? What is the name of it then? How much does it amount to in carrots and turnips? Does pectin differ much from starch in composition? Does it differ from pectic acid?

298. Is sugar found in vegetables? How should vegetables which contain much of it be cooked?

299. What does woody fibre consist of? Does cellular tissue differ from starch in composition? In what respect does woody fibre differ from cellular tissue? How may wood be represented chemically? Is it contained in cabbage-stalks?

300. What changes do the cells of vegetables undergo, in growing old? Is woody fibre digestible?

301. Of the various substances in vegetables, consisting of C, H, and O, do any of them crystallize? Of what nature are the substances met with, more especially in fruits? What are their properties? Are they ever met with in vegetables? In what proportions?

302. Does oxalic acid ever exist in a free state? Does it usually so exist? In what plants more especially is it found in a state of combination? What is the name of the salt?

What appearance does the pure acid present? What are its properties? What is the best antidote to counteract its poisonous properties? What is its composition? Write down its formula from memory? How is an organic acid expressed symbolically? What are the salts of oxalic acid called?

303. Is tartaric acid ever found in a free state? From what salt is it always derived? Whence is that salt obtained? What is the common name of the salt? Is it very soluble in water? Why does it separate from wine? For what chief purpose is tartaric acid employed? Has it any other use? What is its chemical composition? What are its salts called?

304. What fruits does citric acid abound in? Whence its name? What are its most prominent properties? What is it chemically composed of? Is it ever found in the artichoke? In what part? As what? What are its salts called?

305. What is the name of the acid of apples? What other fruits does it occur in? Whence its name? What is it composed of? What are its salts called?

306. Are binary and ternary compounds alone of importance? What, then, are nitrogenized substances? To what extent are binary, ternary, and quaternary compounds contained in milk? What nitrogenized compounds are contained in bread?

307. Are gluten and albumin the only compounds in flour?

308. What does gluten contain in addition to gliadin? What is fibrin? Of what is it composed?

309. What is a further component of flour? Why so called.

310. What is legumin? In what family of plants does it abound? What are its properties? With what is it generally considered identical? What gives solidity to the kernel of the almond?

311. Do the various nitrogenized constituents differ much from each other?

312. Does the value of esculents depend much upon the quantity of nitrogen in them? How much nitrogenized matter is contained in wheaten flour? How much in green peas? Is there more in rice than potatoes? Which vegetable contains least?

313. What elements, besides C, N, H and O, are to be met with in albumin? Is the quantity of sulphur and phosphorus great? Does casein contain phosphorus?

314. Name some oils, &c., in which sulphur abounds? What country furnishes the chief supplies of sulphur? What is its specific gravity? What effect has heat upon it? What is its common name? What purposes in the arts does it subserve? What element does it resemble in its chemical relations?

315. From whence is the phosphorus of the albumin of vegetables obtained? Is it ever contained in the soil in an uncombined form? What is the name of the salt which more especially abounds? Whence do animals obtain phosphorus or its compounds? From what source is phosphorus obtained? What is its appearance? Its specific gravity? What is its combining proportion? How is it preserved? Why so? Is it dangerous to handle? What is its name derived from? To what is the phosphorescence of the glow-worm supposed to be owing? Is phosphorus at all used in manufactures?

316. When phosphorus burns in air, what compound is formed? What is phosphoric acid composed of? Has it any affinity for water?

317. What are the names of the five nitrogenized constituents of vegetable food? Upon the presence of what substances does the value of food depend? Does the quality of flour vary at all? Why may we conclude that the nitrogenized parts of plants are not alone suitable as food?

318. Define a vegetable? In what respect does an animal differ?

319. Do the constituents of meat differ much from those of vegetables?

320. What color is the blood of vertebrated animals? What temperature has it usually? What is the cause of the alkalinity of blood? What does the word mean?

321. In what respect is blood like milk?

322. When blood is left to itself, what change does it undergo?

323. What is the name of the clear liquid part of blood?

324. What is the clot? By what other name is it known?

Is fibrine contained in the blood? How may it be obtained? What is its character? What is the word hæmatosin derived from? State what you know of its nature? What is the name of the other component of the globules of blood?

325. What is meant by the ashes of blood? How are they prepared? What do they consist of? Do we find them in vegetables? In which do they most abound?

326. What is meat chiefly composed of? What is it mixed up with? What affords a good illustration of fibrin? Is the basis of fish and fowl the same? Is broth acid? To what acids do we ascribe the cause? Is meat alkaline or acid? What part does Liebig suppose the acids and alkalies of the body to perform?

327. To what is the smell of roast meat attributable? To what substance more especially is the tenderness of roast meat due? What influence does hot water exercise upon albumin? Of what elements does albumin consist?

328. How should boiled meat be cooked? What is the theory of it? What is the temperature of under-done meat?

329. Why is poultry sooner done than meat?

330. What is the use of lard in roasting?

331. How should soup be made? What is Liebig's prescription for beef-tea?

332. What is gelatin? Has it anything to do with the strength of soup?

333. Has the color of soup anything to do with its strength? How may color be given? Do you remember the chemical name of burnt sugar?

334. Why is salt meat deficient in nutriment?

335. What is the use of common salt? How much is contained in blood? Is it ever a matter of commerce? What vegetables contain most salt? What least? What arguments may be used for the necessity of salt? What is the technical name of salt? What is rock-salt? Why so-called? How is salt obtained from natural brine-springs? What is bay-salt? What gives it its bitter taste? How much salt does sea-water contain? In what form does salt crystallize? Why does it crackle in the fire? What two elements does salt consist of? What is chlorine used for? What color

is it? What is its name derived from? Is it dangerous to breathe? What is its specific gravity? Its equivalent? Its symbol?

336. What is hydrochloric acid? What is it composed of? In what part of the body is it found? What is its common name?

337. What is sodium? What are its properties?

338. Is common salt the cause of the less digestibility of salt meat?

339. Are all kinds of flesh of equal value? How is beef distinguished from veal? Is iron contained in the blood? Is it a necessary constituent of food?

340. Does vegetable food contain iron?

341. Does fish differ from beef or veal? Does it suffer loss in boiling?

342. What is the advantage of stewing over boiling?

343. Why is the practice of boiling meat or vegetables with much water objectionable? Which are most wholesome, baked or boiled potatoes? Why?

344. In what liquid is cheese found? What is the chemical name of curd? What is whey? How is it obtained? What are the properties of casein? What is its composition? What, then, is cheese? Does it consist of pure casein? How is Stilton made? Is cheese very digestible? Why not?

345. What is the difference between bone and bone-earth? How much phosphate of lime does cheese contain? What is bone-earth, more correctly speaking, composed of?

346. What, then, are bones composed of?

347. What is marrow?

348. Into what two classes may all kinds of food be divided? Of what should a right diet consist?

349. Can we obtain a right diet by due admixture?

350. What is the object of food? When does man require most? Is it indifferent of what kind the food is?

351. Does the weight of a man increase much in bulk from year to year? What, then, has the food been expended in?

352. Should age and exercise have anything to do with the amount of food taken? Has the weather anything to do with it? How much carbon does a man exhale from his

lungs? Why do we inhale more oxygen on a cold winter's day than in summer? How do the inhabitants of very cold climates keep themselves warm?

353. Should, then, the same amount of food be eaten at all times? Why not? Why does a removal from a cold to a warm climate diminish the appetite?

354. Why should over-drinking be avoided? What may be considered a fair average amount of drink of any kind?



## CHAPTER VI.

### THE CHEMISTRY OF GLASS, CHINA, AND EARTHENWARE.

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355. Of the many beautiful discoveries effected by the ingenuity of man, none is so beautiful, so perfect, in fact so nearly approaching to the productions of nature, as GLASS.

356. When, or by whom, the art of glass-making was discovered, is unknown ; but that it was practised in very ancient times is certain. A kiln of bricks could scarcely be burnt, or a batch of pottery made, but some of the bricks or ware would be, at least superficially, turned to glass.

357. From many writings of the ancients, it is certain that glass was well known to them. The glass-works of Sidon and Alexandria enjoyed considerable reputation in the time of Pliny. From thence, at one time, Rome was supplied. It is asserted that Nero paid a sum equal to £50,000 for two glass cups with handles, not remarkable for their size, but valuable for their transparency. However, it was not until long after the time of Nero that the Roman artisans became proficient in

the art of glass-making. One of the most celebrated specimens of ancient art, is the Portland Vase in the British Museum. It was found about three centuries ago, enclosed in a marble sarcophagus, in the tomb of Alexander Severus, who died A.D. 235. The body of the vase is deep blue glass, and is ornamented with delicate white opaque figures in low relief, in the style of cameos.

358. In the thirteenth century, the manufacture of glass was successfully prosecuted on an extensive scale at Venice, where it was probably introduced by the crusaders, who had contrived to learn the glass-making processes of the Phœnicians during the Holy War. The quality of the drinking-glasses and mirrors manufactured at Venice has ever been highly extolled, and the artisans of that city continued to supply the greater part of the glass vessels required for all Europe, during two or three centuries.

359. France was the European state in which the manufacture of glass was next conducted on a considerable scale, the Venetian processes having been introduced there, during the ministry of Colbert, by some French artists who had resided in Venice.

360. The manufacture of glass was not prosecuted on an extensive scale in England, until the middle of the sixteenth century; but it is believed that small glass articles were made at a very early period, the processes being derived, most probably, from the Phœnicians, when trading to our country for tin. The glass rings termed the *glain neidyr*,

or *Druid glass rings*, which are frequently found near Aberfrau Palace, are supposed to have been made by the Druids. Window-glass was first made in 1557, in the Crutched Friars, London; and a flint-glass manufactory was established shortly afterwards at Savoy House, in the Strand. Very little progress, however, was made until 1670, when the processes practised at Venice were introduced here by some artisans from that country, under the patronage of the second Duke of Buckingham.

361. This brief sketch of the progress of the glass manufacture, which has been taken almost verbatim from Parnell's excellent treatise on Applied Chemistry, concludes with the following paragraph from the writings of one of the most celebrated authors of the last century:—

“By some fortuitous liquefaction was mankind taught to procure a body at once in a high degree solid and transparent, which might admit the light of the sun and exclude the violence of the wind; which might extend the sight of the philosopher to new ranges of existence, and charm him, at one time with the unbounded extent of the material creation, and at another with the endless subordination of animal life; and, what is yet of more importance, might supply the decays of nature, and succour old age with subsidiary sight. Thus was the first artificer in glass employed, though without his own knowledge or expectation. He was facilitating and prolonging the enjoyments of light, en-

larging the avenues of science, and conferring the highest and most lasting pleasures; he was enabling the student to contemplate nature, and the beauty to behold herself."

362. Glass, as is well known, is an artificial product. In a natural production, resembling glass in many of its best properties, we recognize *quartz*, or *rock-crystal*; and this mineral, often perfectly transparent and colorless, is so hard as to give sparks when struck with a steel, and is infusible in fire. Rock-crystal is often beautifully crystallized in six-sided prisms, the finer crystals of which are cut into ornaments, and frequently used as a substitute for glass in spectacles; they are then called pebbles, and possess an advantage over glass, in not being easily scratched. *Brown* and *yellow rock-crystal* are found in great beauty in the mountain of Cairngorm, in Scotland. That beautiful gem called *Opal*, is a specimen of pure rock-crystal, combined chemically with water. In fact, all the varieties of beautiful stones, known and valued by young and old, under the various names, *Agate*, *Bloodstone*, *Carnelian*, *Flint*, *Amethyst*, and *Onyx*, are but varieties of melted *sand*, colored by metallic oxides; they are *glass*, of nature's manufacture.

363. The technical names for rock-crystal and the various species of sand, are *SILEX*, *SILICA*, and *SILICIC ACID*. The most finely-powdered *silex* feels harsh and gritty between the teeth, is utterly tasteless, and insoluble in water. It may, therefore,

seem at first sight strange to call such a substance silicic acid, as it appears to be devoid of all acid properties.

364. But it may be here observed that a chemist, by the word acid, does not of necessity mean an oxydized body possessed of an acid taste, and capable of reddening blue litmus-paper. In the earlier days of chemistry such a definition was sufficient, but it was soon found to be incomplete. Not only have acids been discovered which contain no oxygen, but others also, presenting every feature of an acid, except an acid taste and the power of reddening litmus. And these properties they could not possess, because of their insolubility in water; for all substances insoluble in water, or some other liquid, must of necessity be void of taste, as the reflecting reader will at once admit. An *acid* is a combination of an element, usually with oxygen or hydrogen, possessed sometimes, though not necessarily, of a sour taste, but having always the power, under given circumstances, of forming a *salt* by union with a metallic oxide or base. But even this definition is both insufficient and incomplete: a more correct one would be to describe an acid as the electro-negative compound in a salt.

365. The acid properties of silica are only displayed under the influence of considerable heat. At high temperatures it is one of the most powerful acids with which chemists are acquainted.

366. It has been observed above, that silica is naturally insoluble in water; nevertheless, it may be rendered soluble, by several of the mighty agents

which are ever silently in operation in nature. For the supply of the very many plants, into the structure of which it enters, and in which it seems to play the same part as the bones do in animals, silica must become soluble in the soil, or else the delicate stomata or mouths of the rootlets of plants would refuse admission to it. That it does so become soluble, is certain. It is even found in spring and mineral waters: in the boiling Geysers of Iceland, it is contained in such quantities as to be deposited by them in porous masses, not very unlike stalactites. Indeed, silica is *known* to exist in two distinct forms, the soluble and insoluble. The soluble passes into the insoluble, as soon as it has once been separated from its solvent, and dried.

367. The chemistry of silica is simply this. It is not an element, but a compound; in fact, the oxide of an element, called SILICON. In a free state silicon resembles a brown powder, destitute of metallic lustre, but is never found as such. Its symbol is Si, and its equivalent 22. It combines with oxygen in only one proportion, and forms silicic acid,—a definite compound of one eq. of silicon, with three eqs. of oxygen. The chemical formula of silicic acid is therefore  $\text{Si O}^3$ . Its specific gravity is about 2.66; and it is only fusible by the oxy-hydrogen blowpipe.

368. But rock-crystal is not glass. Glass is a fused mixture of combinations of silica, with several oxides; of *silicates*, as the salts of silica are called. As it would be impossible to understand the chemistry of glass, without first considering the nature

of the compounds with which the silica is combined for its formation, it becomes necessary to describe them.

369. *Wood-ash*, *pot-ash*, and *pearl-ash*, are the names given to the more or less pure carbonate of potash of commerce. This salt, which consists of a combination of carbonic acid with potash, is exclusively supplied by the combustion of wood and other vegetable substances; its production, on a large scale, is therefore necessarily confined to those countries in which timber abounds. Thus, in the clearings of Canada and the United States, it is usual to burn the wood which cannot otherwise be employed, for the purpose of collecting the ash which remains. This ash is washed with water, and the washings are boiled to dryness in iron pots,—hence the name *pot-ash*. When this potash is again dissolved in water, and the clear liquid poured off from the sediment and boiled, the *pearl-ash* or carbonate of potash of the shops is obtained.

370. CARBONATE OF POTASH forms, when pure, a white granular salt, soluble in its own weight of water, fusible at a red heat, and possessing great attraction for water. The POTASH of the carbonate is the most powerful basic oxide, combining readily with acids, and forming salts. It is very acrid and corrosive, and is hence commonly called caustic potash. At a white heat it is decomposed by charcoal, and thus the metal POTASSIUM may be separated from the oxygen, with which in *Potash* it is combined. Potassium is a blueish-white metal of great lustre, having a strong tendency to attract

oxygen, and to re-form potash. When simply exposed to the air, it gradually absorbs oxygen; if heated in the air, it takes fire and burns. It even bursts into flame when thrown upon water, depriving that liquid of its oxygen, and liberating its hydrogen. When thus burned, potash is formed, and is found dissolved in the water.

371. The class of bodies to which potash (and soda) belong, is that of the *alkalies*, which are distinguished by their solubility in water, by their power of combining with even the most powerful acids and forming neutral compounds called salts, and by their property of changing, in a remarkable manner, the colors of certain vegetable\* matters. The words *alkali* and *alkaline* have been already explained. Ammonia is also an alkali. This is usually called a volatile alkali, on account of its nature (see pp. 24, 25, and 26); while potash and soda are termed fixed alkalis, as they are not volatile at a red heat.

372. The nature of *KALIUM*, the name by which potassium is usually represented, will now be more intelligible. *K* is the symbol of potassium—the combining proportion or equivalent of which is 40.

373. The oxide of kalium or potash being represented by the symbol  $KO$ ; that of dry carbonate of potash must be  $KO.CO^2$ .

374. When one part of silica, and two-and-a-half parts of carbonate of potash are fused together, the carbonic acid is expelled, and a silicate of potash is

\* Yellow turmeric is turned brown; red litmus blue. Blues are unaltered by alkalies.



formed, which is soluble in water, and known by the name of *soluble glass*. A concentrated solution of this compound in water, mixed with chalk or fine china clay, is sometimes used as a paint, to render wood, paper-hangings, and other like articles, incombustible.

375. When pearl-ash and a great excess of silix are melted together, a nearly insoluble silicate or species of *glass* is obtained.

376. But one of the constituents of glass is SODA. In the same manner as carbonate of potash is obtained by the combustion of land-plants, so in former times was all the carbonate of soda of commerce obtained from the incineration (burning to ash) of sea-weeds. *Barilla* and *kelp* were the names by which the rough carbonate was known in the markets, and twenty-four tons of sea-weed were required for the production of one ton of kelp. A very pure carbonate of soda, which, on account of its cheapness, has been made to supersede in many of the arts, the far more expensive carbonate of potash, is now manufactured on an immense scale in England, by the decomposition of sulphate of soda (Glauber salt). This process will be explained in the next chapter.

377. The CARBONATE OF SODA of commerce is a salt, very large transparent crystals of which may be frequently seen in the windows of oil-shops. It contains no less than 63 per cent. of water of crystallization, a portion of which it exhibits a tendency to lose; and thus we often see the transparent crystals covered with a white powder of carbonate of

soda, having lost half of its water. When heated, it melts in its water of crystallization, and, if the heat be continued, gives off all its water. The dry carbonate thus obtained, is a white powder, soluble in two parts of water, to which it communicates a strong, disagreeable, caustic taste.

378. The SODA of the carbonate is a very strong basic oxide or base, only second to potash in its affinities, or powers of attraction. At a white heat, caustic soda may likewise be decomposed by charcoal, and the metal SODIUM or NATRIUM obtained. It is silver-white, very soft, and oxidizes immediately on exposure to air. It melts at  $194^{\circ}$ . Its specific gravity is 0.972. The eq. of Sodium is 24, and its symbol Na. Soda, being a compound of sodium with one eq. of oxygen, is represented by the formula Na O.

379. The compounds of silica with soda, the silicates of soda, are so similar to those of potash, that it is needless further to describe them. Suffice it to say, that no matter how pure the materials employed, the glass resulting from the use of soda is always possessed of a *greenish* hue.

380. LIME is likewise used in the preparation of glass. The mountain-limestone, forms, as is well known, whole ranges of hills in many parts of the world; this, as well as chalk, calcareous spar, and marble, are mere varieties of CARBONATE OF LIME. It is almost insoluble in pure water, requiring as much as 10,601 parts to dissolve one of pure carbonate of lime.

381. When limestone is heated intensely in the

lime-kiln, it loses its carbonic acid, and becomes *oxide of calcium, lime, quick-lime, or caustic lime*, these being the various names by which the product is known. The pure kinds of mountain-limestone lose about 44 per cent. of their weight.

382. **LIME, OR OXIDE OF CALCIUM**, is a very powerful base, and very caustic. It requires for its solution 750 parts of water. Its most remarkable property is its strong tendency to combine with water. In fact, when a few drops of water are poured upon a piece of quick-lime, it falls down into a fine white powder, evolving, at the same time, a great amount of heat. This operation of *slaking* lime may be constantly seen wherever building operations are carried on; the heat generated in the process is frequently made use of by the workmen for the purpose of warming their tea or coffee, and also for cooking meat. The emission of heat is caused by the union of the water with the lime; the former, becoming solid, gives off the heat necessary for retaining it in a liquid form.

383. Slaked lime is a compound of lime with water, and is called, in consequence, a **HYDRATE OF LIME**; it contains 24 per cent. of its weight of water. In the caustic state, lime does not occur in nature, nor, when exposed to the air, does it long remain so. It first slakes, then gradually absorbs carbonic acid from the air, and becomes again converted into carbonate of lime.

384. Although, as we have seen, carbonate of lime is nearly insoluble in water, it is freely taken up when carbonic acid happens at the same time to

be present. Since all water, except distilled, contains carbonic acid in solution, it is to be expected that lime in this condition should be of very common occurrence; and such is found to be the fact, river and spring water invariably containing carbonate of lime thus dissolved. When such a water is heated to boiling, carbonic acid is expelled, and the carbonate precipitated. This likewise takes place at the ordinary temperature of the air, although more slowly; and thus the formation of beautiful stalactites in limestone caverns, and of deposits upon the ground in many places, is explained.

385. Lime, like potash and soda, is an oxide. It is a combination of oxygen with the metal CALCIUM. It is prepared artificially only with great difficulty, and is not known to exist in nature in an uncombined state. Calcium is a silver-white and very oxidizable metal. Its equivalent is 20 ; its symbol Ca.

386. The important oxide of calcium is represented by the formula  $\text{CaO}$ ; the hydrate by  $\text{CaO}$ ,  $\text{HO}$ . The symbol for carbonate of lime is  $\text{CaO}$ ,  $\text{CO}_2$ .

387. OXIDE OF LEAD, which may be prepared by exposing the grey powder which forms on melted lead to the further action of heat and air, until it acquires a uniform yellow color, is a most important agent in the manufacture of glass. It forms very fusible salts with siliceous matter, and as these are beautifully clear and colorless, its value for the purpose of glass-making may be readily conceived.

388. By further exposure of this oxide of lead to

the action of heat and air, at a high temperature, though below its melting point, it attracts a further quantity of oxygen, and acquires gradually a fine red color. MINIMUM OR RED LEAD is preferred in glass-making to the ordinary oxide (litharge), because its excess of oxygen over that of litharge, although given off at a red-heat, has the power of oxidizing and removing any organic impurities which may have become mixed with the various ingredients, and which otherwise would impair the brilliancy of the glass.

389. GLASS, the manufacture of which will not now be difficult to understand, is altogether destitute of *crystalline* structure. It is, essentially, a compound of silica with potash or soda, lime, and oxide of lead. The silica is employed in greater or less quantity, according to the purpose designed by the manufacturer. Fine white sand is usually employed; sometimes powdered flints, or the white pebbles so abundant in many rivers, are made use of.

390. When the *purity* of the glass is of importance, carbonate of potash or soda is used; while for common glass, wood-ash, barilla, and kelp are sufficiently good. The proportions of the raw materials will vary much, usually about half the weight of the silica being the proper amount. During the process of fusion, the carbonic acid of the carbonates escapes in bubbles; and the glass is ready for use as soon as the melted mass of silicates is free from the bubbles of escaping gas.

391. A glass composed entirely of silica and

potash, or soda, requires a very high temperature for perfect fusion; and this is the chief reason for the employment of litharge, and of red lead.

392. The fusibility is much increased, and the compound is not only more tenacious and workable when hot, but bears changes of temperature better. London *flint-glass*, so celebrated for its brilliant transparency, is prepared with oxide of lead; but in consequence of its softness, it is very liable to become scratched. The composition of flint-glass, according to Faraday, is as follows:—

Silica . . . . .	51·93
Potash . . . . .	13·77
Oxides of lead . . . . .	33·28
Impurities and loss . . . .	1·02

---

100·00

393. The mixture of materials for glass is technically termed *fret*; their fusion is conducted in large crucibles, or glass-pots, made of the most infusible kind of fire-clay, which, in the case of lead glass, are covered by a dome at the top, and have an opening at the side, at which the materials are introduced, and the melted glass withdrawn. At a full-red, which is the working heat, the glass has a very tenacious consistency, and, as it scarcely adheres to polished metal, is easily worked with iron tools.

394. The circular tables of *crown-glass* are made in the following manner: the workman having collected the proper quantity of glass, in the soft pasty state, at the end of his blowpipe, commences blow-

ing, by which the lump is expanded into a kind of flask. The latter is fastened at bottom to an iron rod or puntil, by means of a little fresh glass obtained from the glass-pot, and the blowpipe is removed from the neck of the flask by the application of cold iron. The flask is suddenly made to assume the form of a flat disc or plate, by the centrifugal force induced by the rapid, wheel-like movement given to the puntil. Crown-glass or window-glass, is made of soda, sand, and about six per cent. of lime. (Fownes).

395. *Plate-glass* is cast upon a flat metal table, and polished by machinery. It is composed of 100 parts of silica, 33 of carbonate of potash, and 20 parts of carbonate of lime.

396. It has been already stated, that the use of potash secures a clear, and, indeed, the only perfectly colorless glass. The very beautiful *Bohemian glass* consists, according to Mitscherlich, of—

Silica . . . . .	60·0
Potash . . . . .	25·0
Lime . . . . .	12·5
Manganese, alumina, and loss	2·5

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100·0

397. One of the most important parts of the glass-making process is that of *annealing*. This consists in arrangements for allowing the glass to cool very slowly, else it is apt to be brittle and to *fly*, as it is called. Tumblers and wine-glasses, when first bought, are treated by careful housewives in the following manner. They are put into cold water,

upon which a little hay is placed, and this is carefully raised to the boiling point. If the water is then allowed to cool slowly, the glass thus treated will stand any sudden change of temperature. The use of hay or such materials is to prevent any sudden contact of cold: in fact, to allow the cooling of the water to proceed evenly.

398. When transparent glass is maintained for some time at a high heat, but below fusion, it becomes opaque or translucent, fibrous in structure, harder, and less fusible. This is commonly called *Reaumur's porcelain*, and is, in fact, crystalline glass.

399. The various kinds of glass have different degrees of hardness; the surface of glass being harder than the interior. The diamond is employed to cut it, for which purpose, the angles of the diamond should have a peculiar form. The curved facets of the diamond crystal present also curved edges, and while the point barely enters the glass, the curved edges or shoulders act like a wedge to split the glass in the direction of the cut.

400. Glass is also very elastic, as may be shown by any strip of window-glass.

401. The various *colors* are communicated to stained glass by metallic oxides. Oxide of manganese produces an amethyst color; oxide of cobalt, a blue; oxide of gold, a purple; sub-oxide of copper, a ruby-red; oxide of copper, a green; oxide of silver, a yellow; oxide of chrome, a green; oxide of iron, a bottle-green, &c.

402. In glass-painting, the oxides are applied to



the surface of the glass, which is then re-heated until fusion of the coloring-matter in the glass-surface takes place.

403. An opaque white appearance is given to the enamel of watch-faces by oxide of tin.

#### CHINA, STONEWARE, AND EARTHENWARE.

404. The art of making POTTERY is intimately connected with the subject of glass. There are few branches of industry of greater antiquity than that exercised by the potter. The plastic qualities of clay, and its hardening when exposed to heat, are properties which suggested, in very early times, its application to the making of utensils for the manifold purposes of daily life.

405. The *slates* and *tiles* with which our houses are roofed, the *bricks* of which they are built, the *china* of which our cups and saucers, the *earthenware* of which our plates are made, are nothing more than varieties, more or less pure, of the clays and marls so abundant on various spots of the earth, as to have induced men to build their cities upon them.

406. What then is CLAY? Pure clay is a beautifully white substance composed of silica and alumina. It is a true SILICATE OF ALUMINA.

407. ALUMINA (contained in alum) or *argil*, as it is sometimes called, is the OXIDE of the metal ALUMINUM. Native alumina constitutes the *sapphire*. The *oriental ruby* and *topaz* are red and yellow varieties of this earth. *Corundum* and *emery* are minerals consisting of alumina, with less than two

per cent. of oxide of iron and silica. The crystalline varieties of alumina are only second to the diamond, with respect to hardness.

408. Aluminum is another of those rare and little known metals. It has a grey color, and perfect lustre. Its equivalent is 14: symbol Al. When heated in air, it takes fire, and burns with brilliancy, producing alumina: symbol  $Al^2 O^3$ .

409. Alumina, as prepared in the chemist's laboratory, is a white, tasteless, coherent mass, possessing great mechanical attraction for water, which it greedily absorbs. Unlike potash, soda, and lime, it is a very weak base. Infusible in all furnaces, it yet yields to the heat of the oxy-hydrogen blow-pipe.

Alumina then must not be confounded with clay, —a very common mistake.

410. The only clay suitable for the manufacture of *china*, is the so-called CHINA-CLAY, OR KAOLIN; and even this substance is the result of the decomposition of more compound silicates than ordinary clay. The ancient unstratified rocks, but more especially granite and porphyry, contain largely a mineral, *felspar*, which, under certain circumstances, and in the course of time, decomposes, loses its original hardness, and becomes a mass of soft, white, earthy matter, resembling wet slaked lime. The exact nature of the change of felspar into clay is not precisely known; the felspar, a definite combination of silicate of alumina with silicate of potash, acted upon by the carbonic acid of air, and by rain, parts with the silica and potash, and becomes converted into silicate of alumina or china-clay.

411. In the manufacture of *porcelain*, great skill is required in the selection of materials. No oxide of iron must be present in the clay to mar the perfect whiteness of the china. As the clay has to undergo intense and long-continued heat, no easily fusible materials must be left in, or added to it, beyond what is necessary to the production of a semi-translucent glassy texture, and to the prevention of too great shrinking. To effect all these objects, proper proportions of crushed flints and of felspar are intimately mixed with the clay, and great care is taken that the materials, when mixed with the proper quantity of water, form a uniform pasty mass, free from grit. China-ware is formed from it, either on the potter's wheel, or in moulds of plaster. These are then air-dried in a warm room, and being enclosed in baked clay cases, somewhat resembling band-boxes, and called *seggars*, are ranged in the furnace. This is a structure made of brick (somewhat resembling a kiln), having several fire-places, and surrounded by a lofty dome. The cases are so closely packed, as only to leave space for the full play of the flame. Here the ware is kept red-hot for many hours, and the fires are allowed to die out before the *seggars* are removed. *Biscuit-ware* is thus produced. This is afterwards glazed, by dipping it for an instant into a tub containing a mixture of certain proportions of felspar, or of gypsum, silica, and a little porcelain clay, diffused through water to a creamy consistency. The ware absorbs the water, and the powder remains evenly spread over its surface. It is once more

dried, and then exposed to a temperature sufficiently high to melt the glaze.

412. The *colors* employed in painting china are the same metallic oxides which are used for painting and staining glass. The colors are mixed with oil of turpentine or oil of spike lavender, and are applied with a camel-hair brush. When several colors are used, those that bear a high temperature are first laid on, and burnt in, before those which can stand only a lower heat are applied.

413. The *gilding* is generally done by applying finely-divided gold, mixed up with gum-water and borax (a salt of soda and boracic acid). Upon the application of heat, the gum burns off, and the borax, vitrifying upon the surface, causes the gold to adhere firmly. It is afterwards burnished.

#### STONEWARE.

414. A coarse kind of porcelain, containing both oxide of iron and lime, to which it owes its color and its partial fusibility, is called stoneware. The *glazing* is effected by throwing common salt into the heated furnace. This is volatilized, and decomposed by the joint agency of the silica of the ware and of the vapor of water always present. Hydrochloric acid and soda are produced, the latter forming a silicate which fuses over the surface of the ware, and gives a thin, but excellent glaze. (Fownes.)

#### EARTHENWARE.

415. The pottery commonly called *Staffordshire ware* is made from a commoner white clay than

porcelain-clay, mixed with ground flints in considerable quantities.

416. The mode of manufacture is the same as in the case of china, but the glaze is different. It consists of a mixture of about sixty parts of litharge, ten of clay, and twenty of ground flint, diffused in water to a creamy consistency. This glaze is very fusible.

417. The painting on this ware is usually blue, in consequence of the cheapness, and the facility of application of the *oxide of cobalt*. The pattern is first printed off upon paper, which is applied to the plate or other article before glazing. When the ink is dry, the paper is washed off, and the glazing completed.

418. The whitish opaque glaze, which we see on the coarser kinds of earthenware, contains the oxides of lead and tin, and they are therefore unfit for culinary purposes.

## QUESTIONS ON CHAPTER VI.

355. Why is glass so beautiful an artificial product?
356. By whom was glass discovered? How may we suppose it to have been discovered?
357. Was glass known to the ancients? What two cities enjoyed a great reputation for glass? What sum is Nero said to have paid for two glass cups? What is the history of the Portland vase? Describe it.
358. What city was most distinguished for its glass in the thirteenth century?
359. What state followed in the wake of Venice?
360. Who introduced the glass manufacture into England? What about the Druids? Where was window-glass first manufactured? In what year? Who was the patron of the Venetian artizans? About what year?
361. What scientific instruments are alluded to by the writer in "The Rambler," a paragraph from which is given in this chapter?
362. Is glass a natural product? What in nature most resembles it? What is the opal composed of? Name some of the varieties of silex.
363. What are the chemical names for rock-crystal? What are some of its properties?
364. What is an acid? Does such a definition suffice? Give two definitions.
365. Under what circumstances are the acid properties of silica displayed?
366. Is silica ever soluble in water? Do you know any springs which contain it?
367. Is silica an element? What are the properties of silicon? What is the symbol of silica? What its sp. gr.? Can silica be fused?
368. Is rock-crystal glass? What then is glass?
369. What materials are used in the formation of glass?

What names are given to this ash of wood? How and where is it prepared? Whence the name of potash?

370. Describe the appearance and properties of carbonate of potash? What is potash? Is it an element? How may potassium be obtained? What are its properties?

371. To what class of bodies does potash belong? Is ammonia an alkali? What distinction is made between potash and ammonia?

372. What is the symbol of potassium? Its equivalent?

373. What is the symbol of potash? Of what is carbonate of potash composed?

374. What is soluble glass composed of? What use is it put to?

375. How may glass be prepared?

376. What other constituent is commonly employed in the glass manufacture? What is barilla? What use is made of it? How much ash does it yield? Is there any other mode of making carbonate of soda?

377. What is the carbonate of soda of commerce? How much water do the crystals contain?

378. What is soda composed of? How may sodium be obtained? What are its properties? Its equivalent?

379. Do the silicates of soda resemble those of potash? What color has soda-glass?

380. Is lime ever used in the preparation of glass? Name some of the varieties of limestone? Is carbonate of lime soluble in pure water?

381. When heated to redness, what changes does the limestone undergo? What are the various names of the oxide? How much does limestone lose in weight by burning?

382. What is lime? How soluble in water? What effect has water upon lime? What is the common name for the process? What is the cause of the emission of heat? Is any use made of it by workmen?

383. How much chemical water does slaked lime contain? Does quick-lime occur in nature? What change does it undergo by exposure to air?

384. How is carbonate of lime taken up by water? How are stalactites formed? What are the conditions of their formation?

385. What is lime the oxide of? What are the properties of calcium? What is its symbol? What its equivalent?

386. Give the symbols of lime, slaked lime, and carbonate of lime.

387. How is oxide of lead prepared? What is its use? Why are silicates of lead so valuable?

388. What is red lead? Why is it preferable to the common oxide?

389. Has glass a crystalline structure? What are its essential components? What varieties of siliceous materials are employed?

390. What salt is employed when pure glass is required? What is used for common glass? What is the proportion of the raw materials? What gas escapes in the process of fusion?

391. Why more especially is oxide of lead used?

392. What are the properties of a lead glass? What is the name of lead glass? What objection is there to it?

393. What technical name does the mixture of materials for the glass manufacture bear? How is their fusion conducted?

394. Describe the manufacture of crown glass?

395. How is plate glass made? What is it composed of?

396. What is Bohemian glass?

397. What do we mean by the term annealing? How is it accomplished? How should new tumblers, &c. be annealed?

398. What change does glass undergo when long heated? What is it called?

399. Does glass vary in hardness? How does the diamond cut glass?

400. Is glass elastic? How may this be proved?

401. How are colors communicated to stained glass? Can you name some of them?

402. In glass painting how are the oxides applied?

403. How is an opaque-white appearance given to watch faces?

404. What are the chief properties of clay?

405. Name a few household articles made of clay?

406. What is clay chemically speaking?

407. What is alumina? What gems are composed of alumina? What is emery composed of? What is a leading feature of crystalline varieties of alumina?



408. What is aluminum? What are its properties? Its equivalent? Symbol?

409. What are the properties of alumina? Are then alumina and clay convertible terms?

410. What is the name of the only clay suitable for the china manufacturer? What is it formed from? How is it formed?

411. Why may no iron be present in any of the raw materials? Describe the process of manufacture? What is biscuit-ware? How is the glazing done? What is the glaze composed of?

412. What colors are employed in painting china? Explain the process.

413. How is gilding accomplished?

414. What is stoneware? In what does it differ from porcelain? How is the glazing effected?

415. What is Staffordshire ware?

416. What is the glaze made of? What is its chief property?

417. How is the painting done? What is the usual color? Why?

418. Of what nature is the glaze of coarse earthenware? Why does it unfit such vessels for culinary purposes?

## CHAPTER VII.

### CHEMISTRY OF SOAP.

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419. In a chemical point of view, the manufacture of soap is extremely interesting, and forming, as it does, one of the most important articles of domestic use, a short account of its composition, and the process of its manufacture, should not be omitted in a work professing to illustrate household chemistry.

420. The Latin word *Sapo*, and the Greek *Σάπων* (*Sapon*), signifying soap, are undoubtedly derived from the German; for we find the corresponding word *Sepe* is still used in the Low German dialect. Pliny, who makes the earliest mention of soap, declares it to be an invention of the Gauls, though he states his preference for the German over the Gallic soap. Both hard and soft soaps were in use among the Germans. Pliny states it to have been made from tallow and ashes, and that it was employed as a medicine as well as for cleansing purposes.

421. It appears certain, that in remote periods,

clothes were cleansed simply by rubbing, or by stamping upon them in water, without the addition of any extraneous substance. In the sixth book of Homer's *Odyssey*, Nausicaa and her attendant are described as washing their clothes by treading upon them with their feet, in pits which they had filled with water.

422. At a later period, mention is made of the employment of a lye of ashes for washing, and for cleansing oil and wine jars; and there can be little doubt that a solution of wood-ashes, or of impure carbonate of soda, must have been used for these purposes.

423. The ancients appear also to have employed at least one description of plant with a saponaceous juice, as a substitute for soap, but the precise species used cannot now be ascertained; it is also certain that they made use of fuller's-earth much more extensively than is done at present.—(*Beckman's History of Inventions.*)

424. Soaps are, chemically speaking, compounds of the fatty acids with alkalies. The process of saponification will not be difficult of comprehension after the preparation the reader has had in the numerous allusions to the subject. At pages 58 and 59, somewhat of the nature of oils and fats has been described; and although the information there given requires to be somewhat expanded, no new terms will be needed in the explanation of the subject.

425. Our information upon the subject of oils and fats is very considerable; no branch of chemis-

try having been studied with more decided success. These substances form a natural group, in which animal and vegetable fats are closely allied. All oily substances may be divided into *fixed* and *volatile*. When dropped upon paper, both kinds produce a greasy stain, which, in the case of a volatile oil, disappears when heated, but *remains* when produced by a fixed oil. It follows from this, therefore, that the volatile oils alone are odorous; and wherever a fixed oil is perceived to be possessed of smell, we may be sure that it is an indication of the presence in it of a volatile oil. This is well illustrated by the case of butter, (see pp. 88, 89). The margarin and olein have no smell, but the butyrin, amounting to three per cent. gives both smell and taste.

426. A very important property of oils is that of drying or not drying by exposure to air. The terms *drying* and *non-drying* can only be applied to fixed oils, as a volatile oil (for example, attar of roses) so exposed would fly off in vapor. All oils are altered by exposure to air. In the case of the oils used in making paints (linseed, rape, walnut, and poppy), they absorb oxygen, and become hard and resinous. Animal fats and oils, as well as olive and palm oil, likewise attract oxygen, which, however, makes them acid and rancid, but never dries them.

427. We find also in fats, a great difference as regards hardness. Between the very fluid olive oil and hard mutton suet, lie the greatest varieties of consistency,—the difference depending upon the proportion in which the great fatty principles are

mingled. It is as easy to mingle them in any proportions, as to separate them. Thus, olive oil, exposed to a temperature a little above the freezing point, deposits a solid fat, and separates into two distinct substances: *olein*, a liquid, and *margarin*, a solid substance of pearly lustre, separable by simple pressure from the olein. Again, if suet be pressed between folds of blotting paper, whilst the paper will be found stained with olein, the suet itself will have become much harder, less fusible, and less tenacious. It consists now of margarin and *stearin*, the latter a white and lustrous substance.

428. In the process of saponification, the acids of the three substances, olein, margarin, and stearin, combine with the potash or soda; the essentials in this process forming soap, while the glycerin is set at liberty.

429. Soap is therefore a true *salt*, the acid being oleic, margarinic, or stearic, the base potash or soda.

430. The alkaline ingredients of soap are, then, either potash or soda. At page 190, *carbonate of potash* has been mentioned as being used in the manufacture of glass: *caustic potash*, which is employed in the soap manufacture, is prepared from it in the following manner:—One pound of carbonate of potash is dissolved in ten pounds of boiling water in a clean iron vessel. Into it is stirred by degrees, three-quarters of a pound of quick-lime, previously slaked. After a few minutes' fierce boiling, it will be found, on examination, that the carbonate of potash has parted with its carbonic acid to the lime, (which has become in part converted into carbonate

of lime,) and a solution of caustic potash in water has been obtained. It is removed from the fire, and will be found, after the lapse of a very short time, to consist of a clear solution of potash, which should be carefully poured off from the heavy sandy precipitate of chalk, and excess of lime. The solution possesses, in the highest degree, the properties termed alkaline. It dissolves the skin, when subjected to its action. It restores the blue color to reddened litmus paper; combines with, and neutralizes the most powerful acids, and is possessed of a most peculiarly nauseous and biting taste. It unites with fats and oils to form soap, as explained; hence the term *soap-lye* given to the solution of caustic potash.

431. Pure caustic potash, freed from mechanical water, is, like slaked lime, a true hydrate, and is represented by the formula  $KO, HO$ .

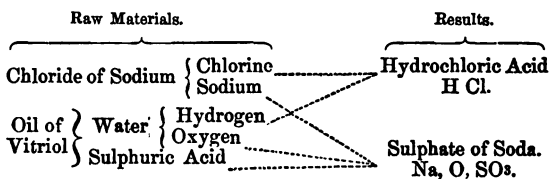
432. On account, however, of its greater cheapness, *caustic soda* is more generally used in the manufacture of soap than potash.

433. The source from whence all carbonate of soda is now obtained, has been indicated at page 192; but the process requires further description. Until within the last thirty years, nearly all the soda of commerce was obtained by reducing marine plants to ashes. Barilla, of good quality, contains about  $\frac{1}{2}$  of its weight of soda. It used to be an important article of commerce, until the salt duties were repealed. The now common process for obtaining soda by the decomposition of sea-salt, was invented by a French gentleman of the name of Leblanc, to-

wards the close of the last century. The supply of Spanish barilla being cut off from France during the cessation of the commercial intercourse between France and Spain, at the time of the first great French Revolution, the national convention of France applied to the French chemists for a new source of soda. M. Leblanc hit upon a plan which is now carried on upon a prodigious scale in both England and France. The duty on salt alone prevented the early adoption of the plan in England: but since its repeal, both kelp and barilla have become valueless as sources of soda.

434. The materials employed in the soda manufacture are: chloride of sodium (common salt), sulphuric acid (oil of vitriol), small coal, carbonate of lime (chalk), and charcoal.

435. The first step is to convert the *chloride of sodium* into *sulphate of soda*—to change sea-salt into Glauber salt. This is accomplished in the decomposing furnace, by sulphuric acid. The chemical change which the salt undergoes, may be expressed by the following diagram:—



From which it appears, that the water contained in sulphuric acid is decomposed; its hydrogen combines with the chlorine: whilst its oxygen oxydizes

the sodium, and enables it to combine with the sulphuric acid.

436. The dry sulphate, technically known as the salt-cake, is, in the next place, calcined (burnt) with chalk and small coal. The proportions recommended by Dr. Ure, are, 10 parts of salt-cake, from 11 to 12 parts of chalk, and five of coal. By the fusion of the sulphate of soda with the coal, the former parts with the whole of its oxygen to the carbon and hydrogen of the coal; carbonic oxide and water are formed and dissipated by the heat, while sulphide of sodium ( $\text{Na S}$ ) remains. But by the admixture of chalk in excess, a still further change takes place: carbonate of soda and oxy-sulphide\* of calcium are formed. The fused mass being raked out of the hearth of the furnace, solidifies, and is known in the market as crude or ball-soda, British barilla, or black-ash.

437. In the preparation of soda-ash, a series of iron cisterns is placed side by side, one a little below the adjoining one. A stream of fresh water enters the uppermost cistern, and flows out through a pipe leading from near its bottom, to the top of the next lower cistern,—the temperature of the whole being maintained at near  $100^{\circ}$ . The crude soda is placed in iron boxes perforated with holes, which are suspended in the cisterns just below the top of the liquid, so that the heavy solution formed sinks to the bottom, and is carried by the pipe to the next

\* An oxy-sulphide is a combination of a sulphide with an oxide: thus, oxy-sulphide of calcium is represented by the formula  $\text{CaS} + \text{Ca O}$ .



lower cistern. The boxes containing the fresh crude soda are placed in the lowermost cistern, and successively transferred to the higher ones, where they meet with a less saturated solution, until in the highest they are exhausted by fresh water, and oxy-sulphide of calcium remains. The lye of the lowest cistern being concentrated, is partly evaporated in leaden pans, during which the crystals of carbonate of soda falling to the bottom, are raked out and drained. The remaining liquor (mother-liquor), containing caustic soda and sulphide of sodium, is evaporated to dryness, mixed with charcoal, or saw-dust, and heated to redness in a furnace, whereby the sulphide is decomposed, and the whole [changed into carbonate.

438. To obtain the crystallized carbonate of soda, the purified ash is dissolved in hot water, and allowed to crystallize in shallow pans of iron or lead. The crystals are composed of:—

Soda . . . . .	21·81
Carbonic acid . . . . .	15·43
Water of crystallization . . .	62·76
	<hr/>
	100·00

Formula  $\text{NaO}, \text{CO}^2 + 10\text{HO}$ . Exposed to air, they fall to powder, and, at the same time, lose one-half of their water of crystallization.

439. The white powder sold by druggists as carbonate of soda, which is employed in making effervescing draughts, and in removing acidity from beer, is a *bi-carbonate of soda*, inasmuch as it contains

*two* equivalents of carbonic acid to one eq. of soda. Symbol  $\text{NaO}$ ,  $\text{CO}^2 + \text{HO}$ ,  $\text{CO}^2$ .

440. The description of the process employed in the manufacture of caustic potash, applies to that of soda. In preparing a lye for the soap-manufacture, the mixture of lime and carbonate of soda, or soda-ash, is placed in large cast-iron vats, and covered with water, and after some hours, the lye is withdrawn through a plug at the bottom of the vat. A purer caustic soda solution may be prepared by boiling, in a clean iron-pot, a solution of two parts of crystallized carbonate of soda, in eight parts of water, with about one part of slaked lime, until a little of the liquid ceases to effervesce on addition of acid.

441. When mutton-fat or tallow is boiled for a time with either potash or soda, it gradually dissolves, forming with the alkali a soap soluble in water.

442. The chief soaps manufactured among ourselves are called white, yellow, mottled, brown, soft, and silicated.

443. Soaps are either hard or soft; the former being compounds of fats or oils with soda—the latter with potash. Soft soap is made with potash and drying oils, either alone, or mixed with tallow, and other coarse and fatty matters. The best hard *white soap* is made from olive oil and soda. The oil is mixed with the lye, and boiled in an iron pot, until the fat is completely saponified, which may be known by its becoming clear and transparent. The boiling is continued until the soap begins to sepa-

rate, and this result is accelerated by the addition of common salt. *White soap* is sometimes composed of tallow and soda. *Yellow soap* is made of tallow, resin, and soda, a little palm-oil being occasionally added. The peculiar appearance of *mottled soap*, formed of tallow, kitchen-stuff, and soda, is communicated by dispersing the lees through it towards the end of the operation. *Brown soap* is made from palm-oil, rosin, and soda.

444. The so-called *silicated soap*, of which large quantities are now manufactured, is made by combining silicate of soda, or soluble glass, with hard soap, in the hot pasty state; from 10 to 30 per cent. may be introduced. Such soap possesses, according to Dr. Ure, very powerful detergent qualities, but it is apt to feel hard and somewhat gritty in use. The silicate of soda, with excess of soda, is obtained by boiling ground flints in a strong caustic lye. (See p. 213, par. 430.)

445. Many substances are used to *adulterate* soap, such as clay, potato-starch, &c., for which improvements, as they are termed, numerous patents have been granted.

446. A true and good soap should be a definite chemical compound, and any excess of water, or the presence of saline matters, detracts from its value.

447. Soap is *soluble* in pure soft water, without decomposition. But when waters contain gypsum, which, with other saline constituents, make water hard, then it is decomposed. At first the water becomes full of flakes, and the cleansing properties of the soap are not brought into play until the action

of the acids of the salts, present in the water, upon the potash or soda in the soap, has ceased. Thus, when gypsum, or sulphate of lime, in solution, is brought into contact with soap, the potash or soda combines with the sulphuric acid, and an insoluble lime-soap separates in white flakes from the water. This fact explains the importance of *soft* water for domestic purposes, and indicates the cause of the great waste of soap by the use of *hard* water:

448. The *cleansing* property of soap is due to the fact, that the greater part of the dirt upon our linen, or our clothes, consists of oily perspiration, grease, or of dust which that grease fixes, and which either cannot be removed at all, or but very imperfectly, by washing in water alone. But if soap be used, its alkaline character displays itself; the grease unites with the potash or soda, and forms, in fact, a soap, which may then be removed by water.

449. The effects of soap upon the SKIN will be more apparent when the nature of it is described. If any one examines his skin he will find its thickness varies in different parts of his body. The more we work or use our skin, the thicker it grows in the parts most exercised. The skin is composed of three coats or layers fitting close to each other, and covering every portion of the body. The innermost layer, which is the thickest, is called the *dermis*, *cutis*, or *true skin*: it is the seat of touch and feeling. It consists of two strata—a superficial or papillary stratum, and a deeper or fibrous stratum called the *corium*. The outer surface of the dermis

is characterised by a number of small conical projections, called papillæ. It is these papillæ which, by their erection, give rise to that peculiar rough appearance of the skin that is observed in winter, and which is known by the name of goose-skin. According to Simon, warts are nothing more than these papillæ elongated and covered with skin proper. Immediately upon the inner skin lies the *outer*, or *scarf-skin* (epidermis), a peculiar horny membrane, thrown out upon the surface of the cutis. With this every one is familiar. When in a state of health, it is always undergoing renewal; the dermis continually pushes up a number of little round cells which become flattened and hard, when in contact with the air, and lap one over another something like the scales of a fish. These scales are not visible to the naked eye; but as there is a never-ceasing supply of the little cells from beneath, so there is a constant wear and rubbing off of the outer surface. From head to foot the process is always going on; and a little attention to this fact will show the great benefit that must result from habitual cleanliness.

450. The skin has a most important duty to perform, on which health is greatly dependent. This duty is the throwing off of the perspiration, which is accomplished by means of the little tubes or pores found in every part of the skin. Commencing at the surface, the tubes pass inwards, twisted like a corkscrew, to the underside of the dermis, where they terminate in little balls or glands, in which the perspiratory matter is formed. The number of

these pores is so great that 3528 have been counted, in a square inch, on the palm of the hand. Assuming each of these pores to be a quarter of an inch in length, and the surface of the body to contain 2500 square inches, the number of pores has been calculated at 7,000,000, and their length nearly 28 miles. This length of drainage, this breathing from the skin, is one of the means employed by nature for throwing off waste material which would be injurious to the body, and for preserving it at an equable temperature. The quantity of watery matter thrown off in the shape of insensible perspiration, amounts to thirty-three ounces in the twenty-four hours: a quantity so enormous, that, if checked by cold or impurity, must disturb the general health.

451. Besides the perspiratory tubes, the whole extent of the skin, except the palms of the hand and the soles of the feet, contains a second set penetrating also through the inner skin, from whence they pour out oil to the surface, which is, by this means, kept smooth and pliant. Were it not for this oil, the outer skin would become harsh and dry, and peel off: but the tubes through which it passes are most numerous on the face, head, and joints, these parts being most exposed to external influences, or to constant friction while in exercise. It also assists in retaining the warmth of the body, and at the same time prevents injury from the occasional contact of noxious substances\*.

452. From these statements we learn that the

\* See Erasmus Wilson on the Skin.

skin, as the natural covering of the body, has the duty of throwing out two fluids, the one consisting of waste and noxious watery matter, the other an oil, necessary to keep it in health. The simplest and best means of keeping the skin in health must be by bathing and washing. But water by itself, be it ever so soft, is not always sufficient. Hence we call in the aid of soap, which dissolves the coat of oil, and more speedily renews the epidermis. (Manual of Public Health.)

453. Fuller's-earth, a grey clay, acts, partly by scouring, partly by absorbing the greasy dirt.

454. If cleanliness be, as the proverb hath it, next to godliness, the manufacture of soap must needs be an important one; so much, at any rate, does the comfort of a community depend upon this useful article, that the consumption of soap has been considered by Liebig to afford a good test of the comparative civilization of nations. In our country it is manufactured on a very large scale; and great quantities are annually exported to foreign countries. Owing to its universal use it has been considered a good means of raising a revenue; and in England, since the reign of Queen Anne, it has been more or less heavily taxed. Only in the present parliament (1853) has the tax been repealed. There is no doubt that taxation has acted as a considerable check upon the free use of soap, and, at the present time, when such general attention is directed to all matters affecting the sanitary condition of the population, the importance of the unrestricted use of soap is generally felt. The quan-

tity consumed, in spite of restrictions, is known to be very large; in 1848 it amounted to nearly 190,000,000 lbs.

455. And here, perhaps, is the fittest place to say a few words on the **CHEMISTRY OF BLEACHING**. In the old process, every piece had to be exposed to the air and light during several weeks in the summer, and kept continually moist by hand-labor. It is remarkable that we cannot yet fully explain the manner in which atmospheric bleaching is performed. We find that air and moisture oxydize and render soluble the color on the fibre of cotton and linen; but whether by the action of ozone or of peroxide of hydrogen, we know not.

456. **PEROXIDE OF HYDROGEN** is certainly a wonderful bleaching agent. It is prepared artificially by communicating nascent oxygen to water. In composition it is water, plus oxygen; its symbol  $\text{HO}^2$ . Peroxide of hydrogen is a colorless, transparent, inodorous liquid, of a bitter astringent taste. Sp. gr. 1.452. It bleaches litmus, whitens the skin, and produces pain. Unfortunately it is troublesome to make, and very difficult to keep.

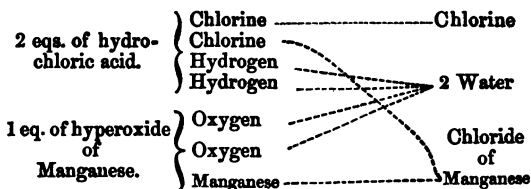
457. The great bleaching agent of modern days is **CHLORINE**; by which means, in one establishment alone, no less than 1400 pieces of cotton are bleached daily throughout the year.

458. Chlorine is contained in common salt, a binary compound of chlorine and the metal sodium. In the process of manufacturing sulphate of soda, (see p. 214) hydrochloric acid is largely obtained: and it is by the action of one part of hyperoxide of



manganese upon two parts of hydrochloric acid, that chlorine is best prepared.

459. The theory of the process will be best illustrated by a diagram, which exhibits the formation of 2 equivalents of water, 1 eq. of chloride of manganese, and 1 eq. of chlorine.

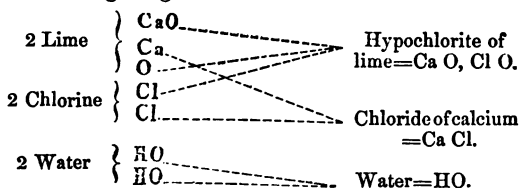


460. Chlorine (from  $\chi\lambda\omega\rho\acute{o}\varsigma$ , chloros, yellowish-green, see p. 167) is a most useful gas, on account of its bleaching or destroying color, and is employed, not only for bleaching linen and calico, but also in calico printing, for producing white patterns on colored grounds. For such purposes, chlorine in the form of gas, would be very unmanageable,—the more, on account of its dangerous properties when inhaled, even in small quantities. Even a solution of chlorine in water is unavailable, partly because the water is possessed of all its dangerous properties, and partly because water can only dissolve twice its own bulk of the gas.

461. A sufficient agent for absorbing chlorine is *lime*: the result of the combination being familiar to all under the name **CHLORIDE OF LIME**, or **BLEACHING POWDER**. The chlorine in this combination is held with such little force, that even the carbonic acid of the air slowly liberates it: but if we require

large quantities, we have only to employ an acid, such as sulphuric or hydrochloric, to effect every purpose.

462. Bleaching-powder was first discovered and manufactured by Mr. Mackintosh: it is prepared on a large scale, by passing chlorine over slaked lime, until the former ceases to be absorbed. Strictly speaking, chloride of lime is a mixture of hypochlorite of lime, chloride of calcium, and water, as the following diagram will shew:—



463. Chlorine is also a great disinfecting agent: in form of chloride of lime, it should be in every household. Even when slowly-generated, it removes the most offensive odors: sulphuretted hydrogen yielding at once to its powers.

## QUESTIONS ON CHAPTER VII.

419. Why is soap important?
420. What is the word soap derived from? Where was it invented? What does Pliny state with reference to it?
421. How were clothes washed in remote periods? Do we read anything about washing in Homer?
422. What other mode of washing was employed at a later period?
423. What juices did the ancients employ as a substitute for soap? Did they ever use fuller's earth?
424. What are soaps, speaking generally? Is the subject of saponification difficult to understand? What do you know of it?
425. Do the animal fats differ from vegetable? Into what classes may all oily matters be divided? What distinguishes them as regards volatility? Which oils are alone odorous? What example have we in the case of butter?
426. What do we mean by drying and non-drying oils? Do animal fats attract oxygen? Do they harden?
427. Is there any difference in the hardness of fats? In what consists this difference? Is it easy to mingle the various fatty matters? Give examples. Describe the difference between olein, margarin, and stearin?
428. Explain the nature of the change which fats undergo when boiled with potash or soda.
429. What then is soap?
430. Is carbonate of potash used in the glass-manufacture? What alkaline ingredients are used in the soap-manufacture? How is caustic potash prepared? What are its properties?
431. In what respect is pure caustic potash like slaked lime?
432. Is caustic soda much used in the soap-manufacture? Why?
433. What was the original source of soda? Is barilla now much employed? Why not? What led to its disuse? Who discovered the new method of manufacture? What prevented its immediate introduction into England?

434. What are the materials employed in the manufacture?

435. What is the first step in the process? Can you explain it? Write the change down upon paper. By what name is the dry sulphate known?

436. What is the next step? What changes do the materials undergo?

437. How is the remaining part of the process accomplished?

438. How is crystallized carbonate of soda obtained? What does it consist of? What is its formula?

439. Is there any other carbonate? What is its correct name? What is it used for?

440. How is the soda-lye obtained? Describe a method of preparing a purer kind of lye.

441. What effect has boiling potash or soda upon tallow?

442. How many kinds of soap are there?

443. How is soft soap made? What materials is the best hard white soap made from? How is it made? How is mottled soap made? What is brown soap?

444. What is silicated soap? What are its properties?

445. What substances are used to adulterate soap?

446. What is the characteristic of a pure soap?

447. Is soap soluble in pure water? Explain the nature of the decomposition which soap undergoes in hard water? What does this fact prove?

448. To what is the cleansing property of soap due?

449. What is the nature of the skin? Of how many coats is it made? Describe them. What gives rise to the sensation of goose-skin? What are warts? What change is the epidermis ever undergoing in health? Why does it prove the necessity of cleanliness?

450. What further duty has the skin to perform? How many pores have been counted on a square inch? What is the chief object of this extent of drainage? How much perspiration is thrown off daily?

451. Is there any other set of pores? What purpose do they subserve? Of what nature are they?

452. State the obvious duties of the skin. Why do we use soap in addition to soft water?

453. How does fuller's earth act?

454. Is a soap-tax judicious? When was it repealed? How much soap is said to be used in England?

455. How was the process of bleaching performed in olden times? What effect has air in the process?

456. What is peroxide of hydrogen? What is it composed of? Of what use is it?

457. What is the great modern bleaching agent?

458. How is chlorine made?

459. What is the theory of the process?

460. For what purposes is chlorine prepared? Why cannot chlorine gas be used? Why not a solution of it in water?

461. What is the best agent for absorbing chlorine? What is the name of the compound?

462. Who discovered bleaching powder? How is it made? Of what is it composed?

463. For what other purpose may chlorine be employed?

## CHAPTER VIII.

### THE CHEMISTRY OF HOUSEHOLD METALS.

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464. THE grand store-house of the *metals* is the earth, which, however, as a rule, does not contain them in the form in which we are familiar with them, but in combination—either with ONE ANOTHER, with OXYGEN, with CHLORINE, or with SULPHUR. When combined with each other they are termed ALLOYS; in combination with oxygen, OXIDES; with chlorine, CHLORIDES; and with sulphur, SULPHIDES or SULPHURETS.

465. The number of metals known to chemists is forty-seven; but many of these are so rare that their properties cannot be made matter of general observation. Household metals, strictly speaking, are only eight in number; viz., GOLD, SILVER, QUICKSILVER, ZINC, LEAD, TIN, COPPER, and IRON. They are distinguished by certain physical properties.

466. Their most striking character is what is commonly termed METALLIC LUSTRE. The thinnest leaves of metals intercept the passage of light so completely, that this property is, no doubt, con-

nected with, if not dependent upon, the degree of *opacity* which all present.

467. Metals are NOT SOLUBLE in water, and are therefore tasteless.

468. The difference of SPECIFIC GRAVITY in metals is most remarkable. Whilst potassium and sodium are lighter than water, gold is upwards of nineteen times as heavy.

469. In point of COLOR, the household metals exhibit every variety. Copper is red, and gold yellow, but the rest present a great degree of uniformity, ranging between the brilliant whiteness of silver and the dull grey tint of lead.

470. In FUSIBILITY, or the degree of heat at which they melt, metals differ most widely. From quicksilver, which is liquid at all ordinary temperatures, to pure iron, which requires the heat of a blast furnace; and from this again to metals of the nature of platinum, which is infusible in furnaces,—a variation of several thousand degrees of heat is to be found. Some metals soften and assume a pasty state before they become liquid. This is the case with iron, which thus admits of being welded, or united together without solder. Thus a bundle of small pieces of iron, when heated to redness, may be joined together into one solid lump by a few powerful strokes of the hammer. It is this property of fusibility which enables us to separate some metals from their dross, and to form every variety of instruments from them when so obtained.

471. There can be little doubt that metals are

capable of assuming all the three forms of matter. Quicksilver boils and *volatilizes* at a temperature much below red-heat, and becomes a *solid* at 39° below the zero of Fahrenheit. Were a sufficient amount of heat obtainable, even those metals which now appear exceptions would, doubtless, be found to follow the same rule.

472. Some metals possess the property of *MALLEABILITY*, or the power of extension under the hammer, to an amazing extent. Of this, gold leaf is a remarkable example. Zinc stands in the middle, between the malleable and brittle metals. The metals arsenic and antimony are entirely destitute of malleability; instead of being flattened out by a stroke of the hammer, they fly in pieces.

473. Now, *DUCTILITY* differs from malleability, as it involves the principle of tenacity, or the power of resisting force. The art of *wire-drawing* depends upon this ductile property of metals.

474. All metals are *CONDUCTORS* of *HEAT* and *ELECTRICITY*. A long piece of wire held in the hand becomes hot when heated in the fire, the heat being conducted to the fingers. A metallic wire several hundred miles long instantaneously conveys electricity from one end to the other.

475. Lastly, it may be said that most metals are capable of assuming regular forms, or of *CRYSTALLIZATION*. The cause of crystallization is not certainly known. When a mineral yields crystals of more than one form, one of these, and generally that from which the others can be most readily obtained, is called the *primitive crystal*, and the others



are considered as modifications of it. The most common crystalline shapes are the cube and the octohedron (p. 13).

476. The natural compounds of metals are called **ORES**. Metallic ores do not generally form large beds or extensive strata in the crust of our globe, but are usually found in clefts, rents, or fissures, called *veins*. The process for getting the ores out of the veins is called *mining*—a term also applied to the getting of coal, salt, &c. The mode of proceeding varies. The mining operations are the simplest when the vein is in strata, composing hills, or rocks, or mountains. If the vein be exposed at the surface of the ground, the mineral is simply dug out, and the excavation thus made serves as a passage to the interior of the mountain, in following the vein. When the vein does not appear externally, or when it takes a new direction, after being followed for some distance, access to it is obtained by *adits* or *levels* (horizontal galleries), dug from the sides of the hill, till the vein is arrived at. Similar galleries are also sometimes constructed to carry off the water which drains through the higher part of the mountain, and which would otherwise impede operations. When the mineral lies in strata considerably below the surface of the earth, then a perpendicular pit or *shaft* (like a well) is sunk to the requisite depth; and from the bottom or sides of this, horizontal galleries are carried to the beds, veins, or strata, sought. The mode of affording support to the superincumbent mass of earth, or rock, left without any, by the excavation of the

mineral, depends upon its value. When the mineral is valuable, the *roof*, or cavern overhead left by the removal of the ore, is propped up by timber or pieces of masonry; but in mines of coal or salt, the whole bed is not dug out, but masses of it are left like columns, to support the roof of the mine. Of course the *ventilation* of mines is important. The mode usually adopted is to cause a current of fresh air, from the surface of the earth, to descend one *shaft*, or one half of a shaft, to supply the place of the impure or noxious air, which is caused to rise through another shaft, or through the other half of the same. This ascent of impure air is effected in most cases by large fires made at the bottom of the shaft, the air in which, being thereby heated, ascends, and causes an upward current, supplied by the air of the mine; and to obviate the formation of a vacuum, fresh air must descend into the mine by another passage.

477. When metals occur nearly pure, they are then said to be found NATIVE.

478. Only a few are thus found, for one of the most general characteristics of the metals, is combustibility in oxygen. As we might expect, from the great heat to which our globe was once exposed, most metals are met with in an oxydized state.

479. Now OXIDES vary both in name and character, according to the quantity of oxygen they contain. The rule as concerning the names of metallic oxides is very simple. That oxide which has the greatest tendency to form a salt with an acid, and which, in its properties, most resembles potash, is

called a PROTOXIDE. The compound next succeeding is called BINOXIDE, DENTOXIDE or PEROXIDE. When there are three basic oxides or salifiable bases, (as they are called) the intermediate grade is called a SESQUI-OXIDE. E.g. the metal tin has three basic oxides, protoxide, sesqui-oxide, and peroxide.

480. Any compound containing less oxygen than a protoxide, and not possessed of basic properties, is called a SUBOXIDE: whilst one containing more oxygen than the highest basic oxide, and yet destitute of acid properties, is called a HYPEROXIDE or SUPER-OXIDE.

481. The names given to salts are derived from the acids they contain. If the name of the acid terminate in IC, that of the salt is made to end in ATE; if in OUS the name of the salt ends in ITE. Thus carbonic acid forms CARBONATES; sulphurous acid, SULPHITES.

482. Supposing a metal to have three basic oxides, then the salts of each are distinguished by the prefixes, PROTO, SESQUI, and PER (bin or deuto). Thus we may have a protosulphate, sesquisulphate, and persulphate.

483. This nomenclature is by no means complete, but will explain every term employed in the present and in former chapters, and is a fit introduction to the subject of metals proper.

1. GOLD. Latin, AURUM. Symbol, Au. Eq. 197. Sp. gr. 19.26.

484. Although traces of this noble metal are to be met with in every country in Europe, yet the labor of obtaining it is so great, as to render it the most expensive of all metals. It is always found native, usually associated with quartz and other substances, and sometimes beautifully crystallized.

485. In the time of Queen Elizabeth, it was found in considerable quantities in the alluvial soil near the lead-hills of Scotland, and in Cornwall in several of the *stream-works*. It is also met with in County Wicklow, Ireland, but the cost of labor exceeds the value of the gold.

486. The richest mines in Europe are those of Hungary and Transylvania, there being no less than forty worked in these provinces, producing annually about 50,000 ounces of gold. The veins, too, of these mines are the largest in Europe, being rarely less than from eighteen to twenty-five feet, and in some parts, upwards of one hundred and twenty feet thick. They are, however, not extensive.

487. In Africa, where, from the limited population and want of cultivation of the people, labor is worth little, considerable quantities of gold are obtained by the negroes, by washing the sands of rivers. Such is the origin of the *gold-dust* of commerce.

488. In the Russian provinces in Asia, gold is found in ever-increasing quantities, and it is from this source that, of late, Europe has been supplied.

489. Immediately after the discovery of America by Columbus, it was observed that the natives of Hispaniola wore ornaments of gold. The quantity, however, must have been small, for, from 1492 to 1500, only £52,000 of gold and silver were sent to Europe. Up to 1519, the annual produce of gold was never greater than £52,000. Cortez at this period conquered Mexico, and he obtained at Chalco, as presents to himself, £70,000 sterling in gold. The celebrated mines of Potosi were discovered accidentally by a Peruvian. Chasing some chamois among the rocks, he laid hold of a small shrub in his ascent, which gave way, and disclosed an immense vein of silver, since called "*La Rica*," or "The Rich." The Indian kept his discovery a secret, and only had recourse to it to supply his wants; but the improvement in his circumstances attracting attention, his companions drew the secret from him, and revealed it to the Spaniards. The annual produce ever since has been equal to £280,000 sterling. In the Brazils, gold was first known to exist in 1543; but the first ore found by a white man in that country was in the year 1693. This discovery led to the colonization of the Minas Geraes, and to all those evils resulting from the lust of gold, with details of which the history of South America abounds. Dr. Walsh mentions that at a very early period, "two parties meeting on the banks of the river, where San José was afterwards built, instead of agreeing in their objects, and pursuing together their operations, set upon each other like famished tigers. A bloody en-

counter ensued, in which many were killed on both sides, and the river was from thenceforth called the Rio das Mortas, or the River of Death. The vicinity of this river," proceeds our authority, "everywhere attests the extensive search for gold formerly pursued here, as it was for a length of time considered one of the richest parts of Brazil, from the profusion of the precious metal found on its surface. All the banks of the stream are furrowed out in a most extraordinary manner, so as to be altogether unaccountable to one unacquainted with the cause. The whole of the vegetable mould was washed away, and nothing remained but a red earth, cut into square channels, like troughs, with a narrow ridge interposed between them. Above was conducted a head stream of water, let down through these troughs, which were all on an inclined plane. The lighter parts of the clay were washed away, and the gold remained behind."

490. That California abounds in gold, is well known. But to us, the discovery of it in Australia is of more importance. We owe the suggestion of the probable presence of gold in that country, to Sir R. Murchison. His remarks having found their way into the Australian newspapers, induced a Mr. Smith to search for it. He found gold, and offered to disclose his discovery to the government, on certain conditions, with which the latter did not think proper to comply. It remained for Mr. Hargraves to re-make the discovery, which he at once published to his fellow-colonists, for which he has been lately rewarded by a gift of £10,000.

491. This first discovery was made in the banks of the Summer Hill Creek and the Lewis Ponds River, small streams which run from the northern flank of the Conobalas down to the Macquarrie. The gold was found in the sand and gravel, accumulated, especially on the inside of the bends of the brook, and at the junction of the two watercourses, where the stream of each would be often checked by the other. It was coarse gold, showing its parent site to be at no great distance. Shortly afterwards gold was discovered in several other localities, especially on the banks of the Turon, some distance north-east of the Conobalas. At the head of the Turon river, among the dark glens and gullies in which it collects its head-waters, in the flanks of the Blue Mountains, the gold got "coarser," occurring in larger lumps or nuggets, but these being more sparingly scattered. The further discovery of gold ensued as a matter of course.

492. It is found usually in the drift clay, sand, and gravel, or lying loose on the surface of the earth. The superficial drift in which the diggings have been carried on, varies in thickness from a few inches to twenty or thirty feet.

493. For the purpose of separation, a quantity of the auriferous sand or clay is taken and washed with water, when the gold, by its own weight, sinks to the bottom, and thus, by repeated cleansing, the gold-dust of commerce is obtained.

494. As this appears a very simple process, the few words of advice given by Mr. Jukes to intending emigrants, are subjoined: "Gold digging is very

hard work—just such work as you see navigators at in a railway cutting, or brickmakers in a brick-pit. You must work hard all day, lie hard all night, with but little shelter, often with scanty food, and with nothing of what you have probably been accustomed to consider necessary comfort.”

495. Having already dwelt sufficiently long upon the subject, any one requiring further information, may obtain it in the “Lectures on Gold,\* for the Instruction of Emigrants about to proceed to Australia.”

496. When gold is embedded in stone, it is stamped to powder, and shaken in an apparatus with mercury and water; a combination of the two metals called an *amalgam*, is formed, after which the mercury is separated from the gold by distillation.

497. Gold is a soft metal, of a beautiful yellow color. Its unchangeableness on exposure to air or water, its beautiful color, its splendid metallic lustre, and its high specific gravity, have caused it to be regarded as the king of metals. The alchemists represented it by the circle ☉, which is also the emblem of perfection, and called it Sol, or the sun. It surpasses all metals in malleability; this is well illustrated by the fact, that thirty ordinary-sized gilt buttons are covered by a single grain of gold. It is also so ductile, that one grain may be drawn into a wire 500 feet in length. The process of wire drawing is very simple; it consists in drawing

\* These admirable lectures have been published by Mr. David Bogue, Fleet-street, at the low price of half-a-crown.



rods of metal through a succession of trumpet-shaped holes in a steel plate, each being a little smaller than its predecessor, until the requisite degree of fineness is obtained. As the metal, in this process, is liable to become hard and to break, that which is intended for wire is previously submitted to the operation of *annealing*, which consists in heating it to redness, and allowing it to cool slowly, by which means its toughness is greatly increased.

498. Gold, in consequence of its softness, is not very durable: for coin, and for elaborate articles of jewellery, it is therefore always *alloyed* with silver or copper. All the gold at present coined is alloyed only with copper; previous to the year 1826, the alloy likewise contained silver—hence the paler color of that coinage. Our English gold coins contain one-twelfth of their weight of copper.

499. Gold-leaf is made by rolling out plates of pure gold as thin as possible, and then beating them between folds of membrane with a heavy hammer, until the requisite degree of tenuity has been obtained. Its thickness amounts to only  $\frac{1}{232000}$  of an inch. The gold leaf is made to adhere to the wood of picture-frames, or other surfaces, by means of size or varnish.

500. Gold-leaf or its amalgam, is also much used in stoppin decayed teeth.

501. The modern process of *electro-gilding* is effected by dipping the articles into a solution of gold (obtained by dissolving oxide of gold in a watery solution of, so-called, cyanide of potassium), into which the poles of a battery are introduced.

502. The oxides of gold and their salts, with the exception only of the above-named solution, and the Purple of Cassius to be mentioned hereafter, are of no importance in the arts.

2. SILVER. Latin, ARGENTUM. Symbol, Ag. Eq.

108. Sp. gr. 10·5.

503. As gold was compared by the alchemists to the sun, silver became the emblem of the pale “silver” moon, under the name of Luna, or Diana; symbol, ♀. It is found in the native state, and in combination with sulphur, as sulphuret of silver.

504. The ores are deposited in veins in mountains, and contain the metal united with others, especially lead. It is never found, like gold, in the sand and alluvial soils washed down by streams.

505. Native silver crystallizes in cubes and octahedrons; but it is more commonly found in irregular masses. In 1478, a rich vein of silver-ore was discovered at Schneeberg, in Saxony, and so large a mass of native metal was cut out, that it served as a dining-table to Duke Albert. When smelted, it yielded 44,000 lbs. of metal.

506. Silver-ore, properly so called, is not common in England; but our lead-ores often contain much of the metal.

507. On the continent, the mines of Schemnitz, in Hungary, are very productive. Every hundred-weight of the ore, consisting of masses of quartz,

filling a vein which traverses a clay-slate, yields about five ounces of silver. At Kremnitz, mines of gold and silver have been worked for a thousand years.

508. The Bohemian mines furnish about 2000 ounces annually.

509. Sweden and Norway also possess productive mines. At Kongsberg, in Norway, the mines yield very considerably, and average annually about 5000 lbs. weight of silver.

510. The most important mines in Asia, those of Kolyvan, in the Altai mountains, have produced as much as one-and-a-half million of pounds weight in the last hundred years.

511. But South America abounds most in silver. The mines of Potosi have been long celebrated. These mines are in a mountain of that name, near the source of the River Plata (Silver), which derived its name from this circumstance. This mountain, which, in the form of a sugar-loaf, rises to a height of 4,200 feet, is filled with silver-ore, and the whole mountain is perforated, in every direction, in search of it. It was opened in 1545, and since that time its produce has been valued at 235 millions sterling! At present the Mexican mines are the most productive of them: the most famous is the mine of Valenciana. The mines of America alone yield silver annually to the value of about £7,250,000 sterling.

512. The chief part of the silver of commerce is obtained by the process of amalgamation, founded on the easy solubility of silver and other metals in quicksilver.

513. The Mexican process consists in making heaps of the stamped ore, and mixing it with about ten per cent. of common salt by treading with mules. The mass is trodden for several days, during which decomposition takes place, and the silver in the ore combines with the chlorine of the salt to chloride of silver. About six times as much mercury is now added as the ore contains silver, which is also incorporated by treading until amalgamation has become complete; that is to say, until the chloride of silver has again parted with its chlorine, and the metal silver has combined with a portion of mercury. The ore is then transferred to cisterns with an upright shaft and arms, which is turned while water is let in, in order to make the amalgam settle and to remove the ore. The fluid amalgam is strained through a strong linen cloth, to remove uncombined mercury, and the solid portion exposed to heat in a distillatory apparatus, by which the mercury is volatilized and collected, separate from the silver, which is left behind in a more or less pure state, according to the nature of the ore.

514. A very large quantity of silver is obtained from some native ores of lead; such ores being known as *argentiferous* (from the Greek *ἀργυρος*, *argyros*, silver). For the purpose of obtaining the silver from this description of ore, the lead is remelted, and allowed slowly to cool. The portion which first crystallizes is nearly pure lead; the alloy of silver, being more fusible than lead itself, is drained off, and found to contain all the silver. The further process depends upon the fact that lead

oxydizes easily, whilst silver has no such tendency. And in this lies the difference between NOBLE and BASE metals. The former not only do not easily oxydize, but, on application of heat, their oxides part with oxygen, and are reduced to the metallic state. The opposite is the case with the base metals; they easily oxydize, *tarnish*, or *rust*. When, therefore, this silver-lead is exposed to a red-heat on the shallow hearth of a furnace, while a stream of air is allowed to play upon its surface, the lead rapidly oxydizes, and the oxide is constantly swept away by the blast. When the chief part of the lead has been thus removed, the residuum is placed in a shallow dish made of bone-ashes, and again heated. The last of the lead is now removed; it becomes oxydized, and sinks into the bone-ash, while the pure silver remains behind, exhibiting all its native brilliancy.

515. Pure silver is the whitest of all metals; it has considerable brilliancy, and takes a high polish. It is harder than gold, and melts at about 1873° F., but does not oxydize. It resists the action of air and water. It is highly malleable and ductile, and may be extended into leaves not exceeding  $\frac{1}{10000}$  of an inch in thickness, and drawn into wire far finer than human hair.

516. And yet silver, notwithstanding its beautiful lustre, does not admit of extensive employment for decorative purposes, on account of the facility with which it tarnishes. And this is due to the action of sulphur, and not to oxydization, for silver is a noble metal. The reader knows that a silver

spoon tarnishes in the mustard-pot (the bowl of which is in consequence usually gilt), and that a watch in time becomes dull in his pocket: he must also have observed how of late silversmiths have been compelled to light up their shops by gas-lamps placed without, instead of within. And why? On account of the escape of sulphur in some form or other. From the presence of sulphur in the oil of mustard and the oil of eggs, the formation of sulphurous acid from ill-purified gas, and the separation of sulphuretted hydrogen from the various kinds of decay and putrefaction, some source of tarnishing may be said to be ever present. The more or less black **SULPHIDE OF SILVER** is composed of 1 eq. of silver and 1 eq. of sulphur: its symbol is therefore  $\text{HgS}$ . It is found native in a crystallized state: diffused throughout argentiferous lead-ores, sulphide of silver may be said to constitute the most abundant ore of silver.

517. Silver plate and coin are formed of an alloy of silver with copper. By the addition of a small quantity of copper, silver becomes harder, while its whiteness is scarcely impaired. The standard silver of England contains, in 12 parts,  $11\frac{1}{10}$  of pure silver, and  $\frac{9}{10}$  of copper. When such silver is heated to redness in the air, it blackens, from the formation of black oxide of copper; if this be removed by immersion in hot dilute sulphuric acid, a film of pure silver, called *blanched* or *dead silver*, remains. The blanks for coins are treated thus before they are struck, whence the *whiteness* of new coin.

518. The better kind of *Sheffield plating* is performed by the application of a plate of silver to the surface of the copper, which is afterwards beaten or drawn out.

519. *Electro-plating* is now more usually employed. The silver-bath is prepared by dissolving about half-an-ounce of oxide of silver in a solution of four ounces of cyanide of potassium, in a quart of warm distilled water. The beauty of the metal, and its freedom from injury by all ordinary kinds of food, render it well adapted for culinary purposes, and it is now frequently used for lining the inside of saucepans; but owing to the porosity of the electro-silver coating, it should be kept scrupulously clean, all contact with acids being avoided.

520. The only basic oxide of silver is the PROTOXIDE,  $\text{AgO}$ . NITRATE OF SILVER,  $\text{AgO}, \text{NO}^{\text{e}}$ , is easily prepared by dissolving silver in nitric acid; it forms a perfectly clear and colorless solution. By exposure to light, it is again partially reduced to the metallic state, and minute particles of silver, in form of a fine black powder, separate. It is very caustic, and easily destroys both skin and flesh when concentrated. Indeed, such a solution of nitrate of silver, evaporated to dryness, fused, and cast in small cylinders, forms the *lunar caustic* of medicine. It is employed by surgeons for cauterizing, or burning away the diseased flesh in wounds.

521. *Indelible or marking ink* is but a solution of nitrate of silver in water, thickened by gum arabic. The black deposit in linen is metallic silver in a fine state of division.

522. Nitrate of silver is likewise one of the ingredients of hair-dyes: its employment for such purpose is both foolish and dangerous.

523. CHLORIDE OF SILVER,  $\text{AgCl}$ , is a not uncommon ore, especially in Chili: it forms the *horn-silver* of mineralogists. Artificially, it may be produced by the addition of common salt, or indeed any soluble chloride, to a soluble salt of silver. It falls as a white curdy precipitate, insoluble in water: when heated, it melts and forms a horn-like substance, which may be cut with a knife. Every hundred parts of horn-silver contain 24.7 of chlorine.

524. The beautiful designs produced on paper in different shades of brown, and distinguished as the *Talbotype* and *Calotype*, are obtained by saturating the paper with various salts of silver, such, for example, as the chloride just noticed, and then exposing it to the regulated action of light. Wherever the light falls the paper darkens, owing to the production of metallic silver, or its suboxide.

525. FULMINATING SILVER is a compound of ammonia with the oxide. It possesses exceedingly dangerous explosive properties, which are better exhibited out of doors than in the household.

3. QUICKSILVER OR MERCURY. Latin, HYDRARGYRUM. Symbol  $\text{Hg}$ . Eq. 202. Sp. gr: 13.56.

526. This metal, which is of great importance in



medicine and in the arts, affords the only example we possess of a metal fluid at the temperature of most climates. Its silver-white color and its fluidity gave rise to its name; the word Hydrargyrum being derived from the Greek *ὑδωρ* (*hudor*), *water*, and *ἀργυρος* (*argyros*), *silver*.

527. On account of its mobile, restless character, the name of the heathen god *Mercury* was given to it: and even now-a-days, in the term mercurial applied to an individual, the meaning has been retained.

528. It has been known from very remote ages. Pliny states that the Greeks imported CINNABAR, or SULPHIDE OF MERCURY, from Almaden, in Spain, 700 years before Christ; and in his time the Romans used annually some 300 tons from the same source. These mines even now yield about one-half of all the rest in the world.

529. Only recently has it been found in great purity and considerable quantity in California.

530. The other principal mines of mercury are in Peru, in South America; in China; and in Spain. The most celebrated, however, are those at Idria, in Carniola, where the metallic vein occurs at a depth of 720 feet. The mineral products of this mine are so varied, that the modes of carrying on operations differ from any other. In some parts pure mercury distils in globules from the rock. The ore is raised in square boxes, by means of a water-wheel; and besides metallic mercury obtained from the ore by distillation, all the preparations of mercury, used in medicine and the arts, are either

found naturally, or are manufactured at Idria. From the great heat of the mines, and the unwholesome vapor of the metal, the miners suffer severely. They soon lose their teeth from salivation, and few survive their fortieth year. Cattle cannot be reared, nor will fruit or grain ripen in the neighborhood. The inhabitants of the town are fearfully afflicted with toothache. The miners become so impregnated with mercury, that a piece of brass, rubbed between the fingers, becomes white like silver.

531. The process of obtaining this metal from its ordinary ore, the **SULPHIDE**, is dependent upon the removal of its sulphur. One method is to heat it with a metal which has a strong affinity or attraction for the sulphur with which the quicksilver is combined. Thus, if cinnabar be heated with iron-filings in an iron retort, the mercury will distil over, and the iron, combined with the sulphur, remain as sulphide of iron in the retort.

532. In Spain another method is employed. The sulphide is reduced in a peculiar furnace without any addition, simply by bringing the flame into contact with the hot ore; the sulphur unites with oxygen and forms sulphurous acid gas, whilst the quicksilver, being a noble metal, has no tendency to become oxydized, and therefore separates in the metallic state.

533. Pure quicksilver is a white, silvery, lustrous fluid, without taste and smell. It volatilizes sensibly at all temperatures above  $70^{\circ}$ , and boils at  $670^{\circ}$ , in which state it may be easily purified from all fixed impurities. At  $40^{\circ}$  below zero, it becomes

malleable, and in the act of solidification, great contraction takes place. At common temperatures it is quite unchangeable in air; but if adulterated with tin or lead, it loses not only much of its fluidity, but also tarnishes easily.

534. The metal is invaluable for physical research, in the thermometer, barometer, &c.

535. Alloys of mercury, with other metals, are termed *amalgams*. The property of forming such amalgams with gold and silver, has been already noticed.\*

536. Next to its *medicinal* properties, quicksilver is most important for silvering looking-glasses; this is accomplished by an amalgam of tin. The process is thus briefly described by Brande:—A perfect sheet of tinfoil, somewhat larger than the plate-glass, is placed upon an even table of slate or stone: quicksilver is then poured upon it, and rubbed uniformly upon its surface with a hare's foot, or a ball of flannel or cotton, until a clean and bright amalgam is formed. Upon this, mercury in excess is poured, till the metal has a tendency to run off; the plate of glass, previously made quite clean, is then brought horizontally towards the table, and its edge so adjusted, as by gradually and steadily sliding it forward, to displace some of the excess of mercury, and float the plate, as it were, over the amalgam, the dross upon its surface being pushed on by the edge of the glass, so that the mercury appears beneath it with a perfectly uniform, clean, and brilliant reflecting surface. A number of square

\* Pp. 239, 240, 242, and 243.

weights, of 10 or 12 lbs. each, are now placed side by side upon the surface of the plate, so as entirely to cover it, and press it down upon the amalgamated surface of the tin: in this way, the excess of mercury is partly squeezed out, and the amalgam is made to adhere firmly to the glass. The mercury, as it runs off, is received into a channel on the side of the table, (which is slightly inclined, to facilitate the draining), and in about forty-eight hours the weights are taken off, and the plate carefully lifted from the table, and set nearly upright, by which the adhering mercury gradually drains off, and the solid crystalline amalgam remains perfectly and uniformly adhering to the glass.

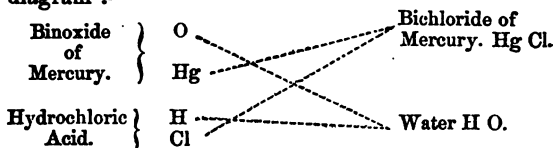
537. Amalgams of silver, and of another metal, CADMIUM, are used for *stopping* decayed teeth.

538. Quicksilver unites with oxygen in two proportions, and forms basic oxides.

539. I. PROTOXIDE OF MERCURY,  $\text{Hg}^2\text{O}$ , is a black substance, insoluble in water. Its basic properties are feeble, but it forms with acids certain salts, one of which is a most useful medicine. CALOMEL or PROTOCHLORIDE OF MERCURY,  $\text{Hg}^2\text{Cl}$  is a very heavy white powder, insoluble in water, and therefore tasteless. It is volatile, and usually prepared by sublimation.

540. II. PEROXIDE or BINOXIDE OF MERCURY,  $\text{HgO}$ , is a much more powerful base than the former, and should more properly be called the protoxide. It forms a red crystalline powder, known by the common names of red oxide and red precipitate. Like all oxides of the noble metals, it is separable by

heat into mercury and oxygen, and is commonly employed for preparing perfectly pure oxygen. Its salts are mostly colorless or white, and are fearful poisons. By dissolving the binoxide in hydrochloric acid, the BICHLORIDE OF MERCURY, or CORROSIVE SUBLIMATE, may be prepared. The mode of its formation will become intelligible by means of a diagram :—



It crystallizes in opaque rhombic prisms, which are soluble in 16 parts of cold, and 3 parts of boiling water. The best antidote against this fearful poison is white of egg, with which it forms an insoluble compound.

541. In the same manner that oxygen combines with the metals, forming various classes of oxides, does sulphur combine with them, forming sulphides. Thus each oxide of mercury has a corresponding sulphide. The only sulphide of importance is the ordinary one which supplies us with mercury. The PER-SULPHIDE OF MERCURY or CINNABAR,  $\text{HgS}$ , contains 86.21 per cent of the metal : it is a compound of one eq. of each element. It sometimes occurs in beautiful crystals, especially in the Palatinate; more usually it is massive and varying in color, from a bright cochineal-red, to brownish red, and even lead-grey. That beautiful pigment, *vermilion*, has the same composition, but is an artificial production. It

is most easily prepared by subliming a mixture of 6 parts of quicksilver with 1 of sulphur, and reducing the resulting sulphide to very fine powder. Of all the manufacturers of vermilion, the Dutch are the most successful; the best is therefore imported from Holland. Its use is not confined to painting; but it is also valuable as the coloring agent of red sealing-wax.

542. A *fulminating* powder is also prepared from mercury, which is most extensively used in the manufacture of percussion caps.

PLATINUM: Symb. Pt; Eq. 99. Sp. gr. 21.5.

543. Though not a household metal, is a noble metal, and of great value to chemists. It is infusible in the greatest furnace heat. Its resistance to most chemical agents and to oxidation at all temperatures, renders platinum of the highest value in the construction of crucibles and other utensils. Platinum is the heaviest of all metals, white in color, exceedingly malleable and ductile, and fusible *only* in the flame of oxy-hydrogen. The Ural mountains in Russia, furnish the chief supply of this metal.

4. ZINC. Latin, ZINCUM. Symb. Zn. Eq. 32. Sp. gr. about 7.

544. This metal is tolerably abundant, and very useful. It is so very slowly acted upon by the air,

that it is now most frequently employed for coating iron for the prevention of rust, and is used for roofing gutters, chimney-tops, &c.

545. Zinc, in the metallic state, seems to have been unknown to the ancients, but they were acquainted with oxidized zinc, under the name of *cadmia*. Pliny makes mention of it as necessary for making brass, and adds, that *cadmia* not only improved the color of copper, but also increased its weight. Galen speaks of its use in medicine. Further it may be stated that Albertus Magnus, in the thirteenth century, was well acquainted with the use of furnace calamine (ore of zinc) in making brass.

546. The first author we meet with who makes use of the name *zinc*, is Paracelsus Theophrastus, who died in 1541. It is certain that even in the middle of the sixteenth century, this metal must have been very scarce. In China and India, however, zinc has long been known; and utensils of zinc, inlaid with various metals, are not uncommon in those countries.

547. Zinc does not occur in the native state. It is found in combination with sulphur, as SULPHIDE OF ZINC; or in the more valuable form of CARBONATE OF ZINC, or *calamine*.

548. The latter is preferred for the extraction of the metal. It is first roasted, to drive off water and carbonic acid, and thus converted into *oxide of zinc*. This being heated in clay pots or crucibles, with small pieces of coke or charcoal at a full red heat, carbonic oxide escapes, and the metal drops

through a hole in the bottom of each pot, by an iron



Fig. 23.

tube, into a vessel of water. (Figure 23, represents a *muffle*, in which the process is conducted. At one end is the curved projection made of clay, through which the gas and vapor of zinc escape. The zinc condenses mostly in the tube, and drops into the vessel of water.)

549. Zinc is a blueish-white metal of crystalline structure, and at ordinary temperatures very brittle. Between  $250^{\circ}$  and  $300^{\circ}$  it is, however, malleable, and may be rolled or hammered into sheets, which retain their malleability when cold. It melts at  $773^{\circ}$ , and volatilizes at a bright red-heat.

550. In commerce, zinc is known by the name of *Spelter*: the largest supplies come to us from Silesia, the mines of which produce annually about 8000 tons.

551. Iron coated with zinc is called GALVANIZED IRON, though no galvanic process is connected with its preparation. The iron intended to be thus prepared is thoroughly cleansed from rust by dilute sulphuric acid, and passed through troughs of melted zinc.

552. Among other important purposes, zinc is employed in the construction of voltaic batteries, used for evolving electricity by chemical action.

553. Zinc has only one oxide. The PROTOXIDE,



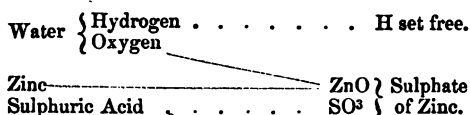
$\text{ZnO}$ , is a powerful basic oxide. It is always formed when zinc is melted in contact with air. At a red-heat the zinc burns with a splendid green light, generating the *oxide*. It is, when pure, a white tasteless powder, being insoluble in water. When heated it turns yellow, but becomes white again on cooling. Its salts are colorless. Those which are soluble in water have a disagreeable metallic taste, and act as emetics. Of the salts of zinc two only require description.

554. CARBONATE OF ZINC,  $\text{ZnO}$ ,  $\text{CO}_2$ , is found native as *calamine*. The Derbyshire ore is composed of—

Oxide of zinc . . . . .	34.8
Carbonic acid . . . . .	65.2
	<hr/>
	100.0

In color it is white, grey, or brown, and it dissolves with effervescence in acids.

555. SULPHATE OF ZINC, or WHITE VITRIOL,  $\text{ZnO}$ ,  $\text{SO}_3 + 7 \text{HO}$  greatly resembles epsom salts. It has an astringent metallic taste, and is used in medicine as an emetic. The crystals are soluble in  $2\frac{1}{2}$  parts of cold, and their own weight of boiling water. They contain 7 eqs. of water of crystallization, a fact indicated by its formula. This salt is constantly formed in the process of making HYDROGEN, by the action of dilute sulphuric acid upon the metal zinc. Water alone has no action upon the metal, but the addition of a little sulphuric acid causes the immediate decomposition of the water. The following diagram will best explain the change:



The anhydrous sulphate of zinc here represented combines at once with water, and forms a solution of ordinary sulphate.

556. SULPHIDE OF ZINC, ZnS, BLENDE, or BLACK-JACK, is a very common native ore of zinc. When pure it is white, but its color varies exceedingly. Its localities are numerous both in Europe and the United States. When employed in the manufacture of zinc, the ore is first roasted, to rid it of its sulphur: the resulting oxide is then mixed with an equal quantity of roasted calamine, and treated in the same manner.

557. Oxide of zinc is employed in making a most valuable paint. It is preferable to lead-paint, because it neither injures the health of the workmen, nor tarnishes by exposure to air; and this because sulphide of zinc is white.

5. LEAD. Latin, PLUMBUM. Symb. Pb. Eq. 104.  
Sp. gr. 11.45.

558. Next to iron, LEAD is the most abundantly diffused of the household metals. Like zinc, it is but slowly acted upon by the air; and, owing to this property, as well as to its malleability, is especially adapted for covering roofs, for cisterns, &c.

559. The most important ore of lead is the *sulphide*, commonly called *galena*.

560. In this country, lead is one of the most important and abundant metallic productions. There are mines in Derbyshire which were worked by the Romans; in Cumberland, Cornwall, Devonshire, and other counties; also in Wales, Scotland, and Ireland: *sulphide of lead* being the common ore in all these localities.

561. It has already been spoken of (p. 243) as often containing silver, and the mode of separating the silver from it has been described. The process for obtaining lead from its ore is very simple. The mixed ore having been broken and washed, is roasted in a reverberatory\* furnace, the temperature being such as to soften, but not fuse it. By this process part of the sulphide becomes oxydized, and converted into sulphate of lead; much, however,

\* *Reverberatory furnaces* are much used when substances

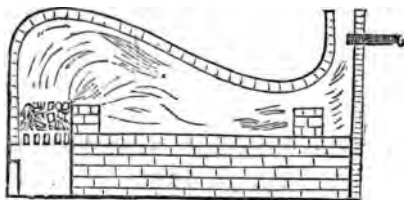
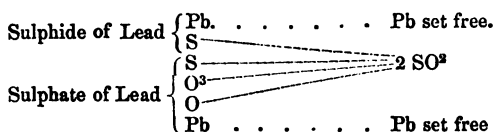


Fig. 23.

are to be exposed to heat without contact with the fuel. The fire-chamber is separated from the hearth by a low bridge of brick-work, and the flame and heated air are reflected downwards by the arched form of the roof. Great heat is obtainable from such an arrangement.

remains unaltered. Now, it is known to chemists, that, when sulphate and sulphide of lead are heated together at a high temperature, they re-act upon one another, and produce sulphurous acid gas and metallic lead. The contents of the furnace are therefore thoroughly raked together, and the temperature increased; the melted lead sinks to the bottom, and is run out into oblong moulds called *pigs*.

562. The subjoined diagram will help the reader in understanding the process.



563. The mines of Great Britain furnish annually upwards of 30,000 tons of smelted lead; in fact, one-half of the whole world's consumption.

564. Pure lead is a blueish-white metal. It is very soft, and, when fresh cut, has much brilliancy. It melts at  $612^\circ$ , and is then, by the action of the air, easily convertible into an oxide. It may be cast, without trouble, into a variety of useful forms.

565. Leaden pipes were used by the ancients for the conveyance of water as at present. The surface of lead readily tarnishes in damp air, and is easily acted upon by soft water, containing oxygen and carbonic acid. Although a slow, it is a most fearful poison. Its salts have a sweet taste, so that in a dilute state it gives no unpleasant warn-

ing of its presence. Fortunately, most waters contain gypsum, the sulphuric acid of which forms an insoluble salt with the oxide of lead. Thus spring waters may be kept with impunity in cisterns of lead, provided the covers be of wood. Otherwise, the pure water which evaporates and settles in drops upon the lid, is liable to dissolve it in small quantities; and thus poisonous properties are communicated to the water.

566. The alchymists gave this metal the name and symbol of *Saturn*,  $\text{h}$ .

567. Lead combines with oxygen in several proportions, only one of which can be properly denominated as a basic oxide.

568. PROTOXIDE OF LEAD,  $\text{Pb O}$ , is prepared on a large scale, by collecting the grey film which forms on the surface of melted lead, and exposing it to heat and air until it acquires a uniform yellow color. In this state it is the *Massicot* of commerce, and when partially fused by heat, the term *Litharge* is applied to it. Protoxide of lead, when pure, has a delicate straw-yellow color, is very heavy, and slightly soluble in water, giving an alkaline liquid. Its sp. gr. is 9.421. It unites with acids, and forms the basis of all the salts of lead, which are colorless, if the acid itself be not colored.

569. CARBONATE OF LEAD,  $\text{PbO, CO}^2$ , is the most important salt of lead, as it constitutes the *white-lead* of commerce. It is prepared in the following manner:—The metallic lead\* is cast into the form of

\* The lead should be of the purest. If it contain iron, the resulting white-lead acquires a tawny hue; and if a trace of

stars or circular gratings. Five or six of these are placed one above another in the upper part of a flower-pot-shaped earthen vessel, into which have been previously introduced a few ounces of strong vinegar. These pots are arranged in a large room, side by side, and are embedded in a mixture of new and spent tan. This first range of pots is then covered with loose boards, and a second range of pots is placed above them, and likewise embedded in tan, and so on till the chamber contains a pile of pots one above the other. In about six weeks time the process is completed. The tan heats, and gives out large quantities of *carbonic acid*: the vinegar rises in vapor, dissolves the lead, inducing the formation of *acetate of lead*, which, as fast as it is formed, is decomposed by the *carbonic acid*, and changed into carbonate of lead. On unpacking the stacks, the lead is either found covered thickly with, or completely changed into, white-lead. This is broken off from what remains of the lead (which is re-melted and re-cast), crushed between heavy rollers, and then ground to fine powder. By repeated washings with water, it is cleansed from all admixture of metallic lead. The whole being at last obtained in the form of a white "paste," is dried and sold in barrels as white-lead. Pure carbonate of lead forms a brilliantly white powder, insoluble in pure water, but slightly soluble in water containing free carbonic acid gas. As carbonate of lead is a fearful poison, it becomes dingy on exposure to light. Derbyshire lead-ore contains traces of cobalt; white-lead made therefrom has usually a pinkish hue in consequence.

poison, and as all soft waters have a tendency to dissolve it, soft water can never safely pass through leaden pipes without being rendered unfit for drinking.

570. ACETATE OF LEAD,  $\text{PbO}, \bar{\text{A}} + 3 \text{HO}$ , is prepared by dissolving litharge in acetic acid. It is generally met with in commerce as a confusedly-crystalline white mass, somewhat resembling loaf-sugar. From this circumstance, and from its sweet taste, it is often called *sugar of lead*. The crystals are soluble in rather better than their own weight of water. *Goulard-water*, so much valued in pharmacy, is a basic acetate of lead, a salt in which the base preponderates over the acid.

571. CHROMATE OF LEAD,  $\text{PbO}, \text{CrO}_3$ , *Chrome-yellow* or King's Yellow, is a beautiful yellow [pigment, much used in calico-printing, and in painting coach-panels. The color is given to the salt by the acid: the metal CHROMIUM deriving its name from  $\chi\rho\omega\mu\alpha$  (chroma), color, because all its compounds are colored.

572. RED OXIDE OF LEAD,  $\text{Pb}^3 \text{O}^4$ , or *Red lead*, is a brilliantly red heavy powder. It is prepared by long exposure to the air of unfused protoxide at a faint red-heat. Made into paint with linseed-oil and turpentine, it forms what the house-painter calls *priming*, it being generally the *first* paint that is applied to new wood or plaster-work. It dries very hard, effectually fills up pores, and preserves the wood. A considerable quantity of red lead is used in coloring common red wafers.

573. SULPHIDE OF LEAD,  $\text{PbS}$ , or *galena*, is the

only important compound of sulphur and lead. It occurs massive and beautifully crystallized in cubes. In lustre the ore resembles the metal, but it is very brittle. Artificial sulphide is a black powder; hence lead-paint always tarnishes in any atmosphere containing sulphuretted hydrogen.

574. *Type-metal* is an alloy of 4 parts of lead, with a metal called ANTIMONY; it is easily melted, and receives a sharp impression from the mould into which it is cast into type. Its hardness is remarkable, and sufficient to withstand the pressure of the printing-press.

6. TIN. Latin, STANNUM. Symbol, Sn. Eq. 58. Sp. gr. 7.3.

575. This metal has been known from the earliest ages. Pliny relates that the Phœnicians traded with Britain and Spain for tin. It still occurs most abundantly in Cornwall; and is found in considerable quantities in Malacca, India, and Germany.

576. The alchemists worked incessantly upon tin, endeavouring to transmute it into silver. They imagined it to be under the influence of the planet Jupiter, and accordingly denoted the metal by the name and symbol ♃ of *Jupiter*.

577. The principal ore of tin is the *native oxide*, but it likewise, though more rarely, occurs as a *sulphide*.

578. The oxide, or tin-stone of Cornwall, is



known by the names *mine-tin* and *stream-tin*, according to the source from whence it is obtained.

579. The principal tin-mines of Cornwall are in the neighbourhood of St. Austle and the Land's End.

580. The mode practised there of reducing the ore is briefly as follows. The ore is pounded, or *stamped*, on the spot, in the stamping-mill, which consists of heavy beams of wood, shod with masses of iron, weighing  $1\frac{1}{2}$  cwt. each. These beams are raised by means of water-wheels, and fall by their weight on the ore, which is placed in troughs, through which a small stream of water runs, in order to wash away the ore as it is pounded fine. One end of the trough is formed of iron plates pierced with holes, through which the ore is sifted, as it were, and passes into other troughs or pits, in which it settles from the water in various degrees of fineness.

581. The ore thus pounded is washed in vats called *keeves*, to free it from all soluble earthy matter and dirt, previous to its being smelted.

582. It is then roasted, to remove the *sulphur* and *arsenic* with which it is always contaminated. Mixed with charcoal and a little lime, it is heated in a reverberatory furnace for eight hours; the charcoal, combining with the oxygen of the oxide of tin, escapes in the form of carbonic acid gas, while the lime, uniting with the silica and other impurities, forms a slag, consisting mainly of silicate of lime.

583. The impure tin thus obtained, is again returned to the furnace, and carefully heated, so as to

melt the tin, which runs off into an iron kettle, while the chief impurities remain unmelted. The tin in the kettle is kept in a state of fusion, and agitated by plunging into it wet charcoal, which causes the impurities to rise to the surface, where they are skimmed off.

584. Thus refined, the metal is cast into blocks, of 3 cwt. each, called *pigs*.

585. The tin which is obtained from the ore washed down by *streams*, is purer and more free from arsenic than that from the veins. The largest *stream-tin* works are at Carnon, near Redruth.

586. The purest kind of tin is sold under the name of *grain-tin*: *block-tin* is less pure.

587. The pure metal has a white color, and emits a peculiar crackling noise when twisted, owing to the sliding of the crystalline plates over each other. Its taste and odor are disagreeable. It is very malleable, as may be inferred from the fact, that tin-foil is less than  $\frac{1}{1000}$  of an inch in thickness.

588. Tin is but little acted upon by air and water. It melts at  $442^{\circ}$ , and may be then easily crystallized.

589. In the manufacture of *common gilt paper*, no gold is used: the paper is covered with tin-foil, upon which a transparent lacquer, colored yellow with turmeric, is afterwards spread.

590. Tin combines with oxygen in three proportions, none of which possess much interest. When heated above its melting-point, it oxidizes rapidly, and is converted into *Putty-powder*, or *Tin-putty*. This substance is a mixture of the protoxide  $\text{SnO}$ ,

with the BINOXIDE  $\text{SnO}_2$ . It is extremely hard, and much used for polishing glass, jewellery, and metals.

591. It is from the BINOXIDE OR PEROXIDE OF TIN,  $\text{SnO}_2$ , that our supplies of the metal are mainly derived. Of the 10,000 tons of metal produced annually over the whole world, England affords one-half.

592. The so-called *Purple of Cassius*, so much employed in enamel-painting, is most probably a combination of SESQUI-OXIDE OF TIN with OXIDE OF GOLD.

593. Sulphur unites with tin, forming three sulphides, only one of which is of importance. BISULPHIDE OF TIN,  $\text{SnS}_2$  was discovered by the alchemists, among whom it excited extraordinary interest, on account of its splendid golden lustre, which induced them to believe that they had transmuted tin into gold. It is much used as an imitation of gold in paper-hangings, toys, and theatrical decorations. It is also called *mosaic-gold* and *bronze-powder*.

594. Some of the *alloys* of tin are important. PEWTER is usually compounded of 20 parts of tin with one of lead, or another metal, BISMUTH. *Tin-plate* is another most useful alloy. Iron-plate and kitchen utensils may be coated superficially with tin, and thus preserved from rusting away. The only objection is, that the iron, if anywhere exposed, has an increased liability to oxidize, or rust. This is especially the case with tin-plate; hence the superiority of iron-plate coated with zinc instead of tin.

7. COPPER. Latin, CUPRUM. Symbol, Cu. Eq. 32.  
Sp. gr. 8.96.

595. Its name its derived from the island of Cyprus, where the metal was first wrought by the Greeks. The brass or *æs* of the ancients, of which they made their implements, both of agriculture and of war, was an alloy of tin and copper. The alchemists called copper, Venus ♀, the name of the protecting goddess of Cyprus.

596. It sometimes occurs in the METALLIC state in masses, varying from an ounce to a ton.

597. It is abundant in the form of *red oxide* and of *carbonate* : but the most important ore, and that from which the metal is chiefly obtained, is the *yellow copper ore*, or *copper pyrites* (from the Greek  $\pi\upsilon\rho$ , pyr, fire). It is usually a compound of one part of sulphide of copper with one of per-sulphide of iron. There are mines of it in Anglesea and Cumberland, but the most extensive and the richest are those of Cornwall and Devonshire. The principal mines lie between the Land's End and Truro, the most important being in the neighbourhood of Redruth. There are upwards of eighty copper-mines in Cornwall, varying in their productiveness from 100 to 1500 tons of copper annually.

598. Besides those of England, copper-mines are worked in Australia, Spain, Saxony, Sweden, Norway, Russia, and Mexico. The principal copper-mine in Sweden is the celebrated one of Fahlun, in

the province of Dalecarlia. This mine is a vast chasm, formed by the artificial excavations for the ore, the bed of which is not a mile in extent.

599. The process of reduction is carried on most largely in South Wales. There the ore is first roasted in a reverberatory furnace, by which the sulphide of iron is oxydized, while the sulphide of copper remains unaltered. The roasted ore is then strongly heated with sand, which combines with the oxide of iron, forming a fusible slag, or glass of silicate of iron, which separates from the heavy sulphide of copper. By a repetition of this process, the iron is got rid of, and then the sulphide of copper begins to decompose in the reverberatory furnace, losing its sulphur and absorbing oxygen. The temperature of the furnace is then raised, and the oxide of copper reduced to the metallic state by the aid of charcoal. The last part of the process consists in thrusting into the melted metal a pole of birchwood, the object of which is to reduce a little remaining oxide by the combustible gases thus generated. (Fownes.)

600. With one single exception, TITANIUM, copper is the only metal which has a red color. It is very lustrous, very malleable and ductile; indeed, next so in degree after gold and silver. Like tin, it emits a smell when rubbed with a moist hand. Its melting-point is between that of silver and gold, and is placed by Daniel at 1996°.

601. Copper is a most useful metal, and many valuable household utensils are formed from it. It is, too, the most sonorous of all metals, and is there-

fore employed for trumpets, and similar musical instruments.

602. Copper also forms part of the metallic currency of the realm, one pound being coined into twenty-four penny pieces.

603. Copper unites with oxygen in two proportions.

604. The RED OXIDE OF COPPER,  $\text{Cu}^2\text{O}$ , is a very weak basic oxide, and is usually called the SUBOXIDE. It is often found native in beautifully transparent ruby-red crystals, and is called RED COPPER-ORE. It imparts a deep rich ruby color to glass, and is the color employed to imitate the ruby and the garnet. Tea-urns are also often coated with it.

605. The PROTOXIDE OF COPPER,  $\text{CuO}$ , is the only oxide which forms important salts. On account of its color, it is commonly called BLACK OXIDE. It is formed whenever copper is heated to full redness. To glass it communicates a green color.

606. Its salts are mostly of a blue or green color, all of them being poisonous. On this account, copper saucepans should be kept scrupulously clean, for we find that when exposed to moist air they become covered with so-called verdigris. The green crust thus formed is a CARBONATE OF COPPER. It is prepared as a pigment, under the name of *green verditer*.

607. MALACHITE,  $\text{CaO}$ ,  $\text{CO}^2 + \text{CuO}$ ,  $\text{HO}$ , which is found in such beauty in the Ural mountains of Siberia, and in Australia, and made into various ornaments, is the native carbonate.

608. SULPHATE OF COPPER,  $\text{CuO}$ ,  $\text{SO}^3 + 5\text{HO}$ , or

BLUE VITRIOL, is of a sapphire-blue color, soluble in four parts of cold and two of boiling water. It is much used in the arts as a source of several blue and green colors; and a saturated solution of it is employed in electrotyping.

609. ACETATE OF COPPER,  $\text{CuO}, \bar{\text{A}} + \text{HO}$ , a salt of a green color, is a species of *verdigris*. It is a beautiful pigment, but a fearful poison. Care should be taken to keep vinegar from all copper vessels, as it is an immediate solvent of any ready-formed oxide or carbonate. A very small amount of verdigris will communicate a beautiful green color to pickled cucumbers or preserved fruits. All such should be regarded with suspicion. Inasmuch as it is very difficult to preserve the green color of vegetables and fruits, it is better to buy them of a pale green or yellowish green color, than to injure health for the sake of pleasing the eye.

610. COPPER-PYRITES,  $\text{Cu}^2 \text{S} + \text{Fe}^2 \text{S}^3$ , is the principal ore of the Cornish mines. It is of a brass-yellow color.

611. The ordinary SULPHIDE OF COPPER,  $\text{CuS}$ , is black.

612. The alloys of copper are very important. Thus *brass* is an alloy of copper and zinc. The proportions vary, and some contain a little lead and tin. *Pins* are usually made of brass and coated with tin. The famous *Corinthian brass* was an alloy of copper. Pliny states, that vases made of this brass were considered more valuable than if made of gold, on account of its beauty. The cutting instruments of the ancients were alloys of copper with five per

cent. of tin. *Tombak*, *Pinchbeck*, *Dutch-gold*, and *Similor*, are alloys of brass with copper. *Bell metal* is an alloy of copper and tin; so likewise is *Bronze*. *Speculum metal* contains, in addition to copper and tin, a little arsenic.

613. Whilst on the subject of alloys of copper, may be mentioned the existence of a beautiful metal called NICKEL. It is found in the Hartz mountains, and in some few other localities. It is a white, malleable metal, fusible with difficulty, and strongly magnetic. Its chief use is in the preparation of several beautifully white alloys, some of which are only inferior to silver. *German silver* is an alloy of 100 parts of copper, 60 of zinc, and 40 of nickel. *China silver*, or *tutenag*, *Britannia metal* and *Argentine*, of which forks, spoons, tea-pots, &c., are made, are alloys in various proportions of copper, zinc, and nickel. (Spoons and forks of any of these alloys, should not be allowed to remain in contact with pickles or any acid sauces.)

8. IRON. Latin, FERRUM. Symbol, Fe. Eq. 28.  
Sp. gr. 7·8.

614. Is the most important of all metals. It has not, indeed, the beauty of color, nor the fineness of quality which gold and silver possess. But the grand difference between iron and other metals is its hardness, and its capability, by a peculiar process, of being made into *steel*, which is so hard that



it can cut every substance in nature, with the exception of the diamond. It is universally diffused over the earth, and there is no soil that does not contain more or less of the oxide of this metal. Iron has been known and employed by man from the earliest ages of his existence, knives and weapons of iron being mentioned in the Books of Moses. The name and symbol of Mars,  $\delta$ , the god of war, were given to it by the alchemists.

615. NATIVE IRON is found in small quantities in the Ural mines. Those immense masses of metal, known as meteoric, are composed mainly of iron.

616. But the source from whence the quantities for the world's supply are drawn, is not from native iron, but chiefly from its OXIDES, CARBONATES, and SILICATES.

617. One of the most valuable ores is the MAGNETIC IRON ORE, or LOADSTONE. It is black and lustrous, and sufficiently magnetic to take up a needle. It is abundant at Roslagen, in Sweden, and is manufactured into a kind of bar-iron, from which the best steel is made.

It is more readily fusible than iron, and is of an iron-black color. It is a chemical compound of the only two basic oxides of iron, and is, in fact, composed of one eq. of each oxide.

It consists, in 100 parts, of—

PROTOXIDE OF IRON, $\text{FeO}$ . . .	31.00
PEROXIDE OF IRON, $\text{Fe}^2\text{O}^3$ . . .	69.00
	<hr/>
	100.00

Loadstone is therefore represented by the formula  $\text{Fe O} + \text{Fe}^2 \text{O}^3$ .

618. RED-IRON-STONE, or HÆMATITE, is far more abundant than the former, and abounds near Ulverstone, in Lancashire. From it some of the best iron-plate and wire are made. It is of a brown-black or ochreous color. It is a true PEROXIDE, or *red oxide*, or *sesqui-oxide of iron*—for it is known by all these names. When pure, it consists, in 100·00 parts, of—

Iron . . . . .	69·23
Oxygen . . . . .	30·77
	<hr/>
	100·00

Its symbol is therefore  $\text{Fe}^2 \text{O}^3$ .

619. There are also several varieties of the *hydrated hæmatite*, which is represented by the formula:  $3 \text{HO} + 2 \text{Fe}^2 \text{O}^3$ . This ore is even more common than hæmatite.

620. *Clay-iron-stone*, so called on account of the large admixture of clay with the oxide of iron, is likewise abundant. The coal formations of Staffordshire, South Wales, and Scotland, from whence the great supply of British iron is obtained, contain it in form of carbonate of the protoxide of iron.

621. PROTO-CARBONATE OF IRON, when pure, consists, in 100 parts, of—

Protoxide of iron . . . . .	62
Carbonic acid . . . . .	38
	<hr/>
	100

Its formula is therefore  $\text{Fe O} + \text{CO}^2$ .

622. Our English iron is not, however, made from a pure carbonate. Clay-iron-stone is a mixture, as the following analysis of a Scotch ore proves :—

Protoxide of iron . . . . .	45·84
Carbonic acid . . . . .	33·63
Lime . . . . .	1·80
Magnesia . . . . .	5·70
Silica . . . . .	7·75
Alumina . . . . .	2·43
Coal . . . . .	1·83
Water . . . . .	1·02
	<hr/>
	100·00

623. The process of the manufacture of the metal is simple, unless we enter into the minutiae of the process. The clay-iron-stone is first *roasted* with coal, by which the carbonic acid is removed from the carbonate, and the metal remains in combination with oxygen, as red oxide of iron. It is now ready to be *smelted*. This process is conducted in the so-called blast furnace (see fig. 25), a tall building, fifty or sixty feet high. It is open at the top, to admit the raw material, and for the escape of gases, but closed at the bottom, the fire being maintained by a blast of hot air introduced by the so-called tuyere-pipes, as may be seen in the section. Into this blast-furnace a mixture of equal weights of roasted ore and coal, with one-fifth of limestone, is thrown, and powerfully heated by means of a current of hot air, introduced at the bottom. The carbon of coal enters into combination with the oxygen of the ore, and

forms carbonic acid, which, together with nitrogen, carbonic oxide, carbonetted hydrogen, and sulphurous

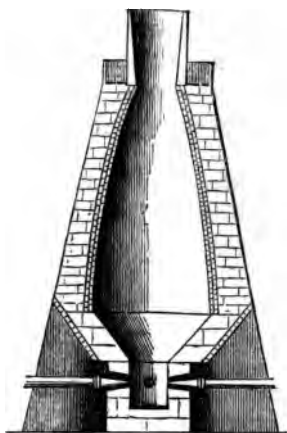


Fig. 25.

acid, escapes in the form of gas. The lime unites with the silica of the ore, and with other impurities, and forms a *slag*,\* which, being lighter than the metal, swims on the surface. In the course of a day and night the iron is found in metallic shape, and is drawn off by taking out a plug made of clay, inserted at the bottom of the furnace. It is allowed

to run into a bed of sand, which is formed into channels and furrows.

624. Iron *cast* in these channels of sand is called *pig-iron*. Such iron is combined chemically with carbon.

625. The quantity of metal obtained in one furnace from good materials averages forty tons per week, requiring about twenty tons of coke and

\* The slag is an impure glass; its chief employment is in the construction of roads. It is green, blue, and brown in color, derived from the combination of a portion of oxide of iron, with the clay, lime, and sand. The slag is, therefore, a silicate.

forty tons of limestone. The metal from the ore is usually from twenty-five to thirty per cent.

626. The quantity of air thrown into the furnace every twelve hours amounts to about sixty tons weight; so that, in fact, the air, which is looked upon as so light a substance, constitutes a greater weight than that of the ore, limestone, and coke put together.

627. Cast-iron is of two kinds, *grey* and *white*. It fuses at a temperature of 2786°. The following analysis will prove that neither kind consists of pure iron :—

	Grey cast iron.	White cast iron.
Iron.....	95·3 . . . . .	94·33
Carbon .....	2·2 . . . . .	2·69
Silicon.....	2·5 . . . . .	0·23
Phosphorus ...	0·0 . . . . .	0·16
Manganese ...	0·0 . . . . .	2·59
	<hr/> 100·0	<hr/> 100·00

628. Grey cast-iron also very frequently contains both manganese and phosphorus.

629. *Wrought-iron* is made from cast-iron by the process of decarbonizing. The removal of a portion of this carbon, or the *puddling process*, is effected by introducing the metal into a reverberatory furnace (see p. 258); after being powerfully heated and stirred for a few hours, it is made into balls, which are 'hammered, and drawn between rollers while still hot, into bars.

630. Wrought-iron surpasses all metals in tenacity; hence its great value in the construction of

suspension-bridges, girders, cables, and other works where great strain has to be resisted, or heavy weights to be suspended.

631. PURE IRON is a metal of a silver-grey color, fusible\* at a temperature of  $3330^{\circ}$ ; it is therefore far less fusible than either cast or wrought-iron; and it would even be a matter of very great difficulty to turn "scrap iron" to account, if it were not for an invaluable property possessed by iron, which compensates for its hard fusibility. This property of *welding*† is a very important one. Owing to this property, when fragments of iron are put together in form of faggots or bundles, and heated to whiteness, they may be joined into one mass by a few strokes of heavy hammers.

632. In ductility and malleability iron is inferior to many metals. It is attracted by the magnet, and may be rendered permanently magnetic.

633. In dry air and in pure water, at ordinary temperature, iron does not lose its metallic lustre.

634. But in moist air, as well as in common

\* As the utmost range of a quicksilver thermometer is  $660^{\circ}$ , a degree which cannot be exceeded without bursting the thermometer-tube by the vapor of the boiling mercury, it may be asked, how do we ascertain higher temperatures? By an instrument called a PYROMETER (from  $\pi\upsilon\rho$ , *pyr*, fire, and  $\mu\epsilon\rho\mu\epsilon\omega$ , *metreo*, I measure). It is formed of a bar of infusible *platinum*, the expansion of which by the heat of a furnace having been well ascertained, is thus made the continuation of the thermometer scale, beginning at the boiling-point of mercury.

† Platinum, it will be remembered, possesses the same property.

water, it *oxydizes* or *rusts* from the formation of hydrated peroxide of iron. Polished iron may be prevented from rusting, by immersion in a solution of potash or soda, or by being embedded in quick-lime. The object of coating iron with zinc is to effect a similar purpose.

635. *Steel* is prepared by heating iron in contact with charcoal. Bars of Swedish iron are embedded in charcoal-powder, contained in a crucible capable of resisting heat, and exposed for hours to a bright red-heat. The iron takes up about  $1\frac{1}{4}$  per cent. of carbon, and becomes harder. The product is called *blistered* steel, from the appearance of the bars. The texture is improved by welding a number of these bars together, and drawing the whole out under a light tilt-hammer. The most wonderful property of steel is that of becoming very hard when suddenly cooled. If a piece of steel be heated to redness, and then plunged into cold water, it becomes capable of scratching glass. If re-heated, and allowed to cool slowly, it again becomes as soft as ordinary iron. The articles forged into shape are first hardened in the manner described; they are then *tempered*, or *let down*, by exposure to a proper degree of annealing heat, which is often judged of by the color of the thin film of oxide, which appears on the polished surface. Thus a temperature of about 430° F., indicated by a faint straw-color, gives the proper temper for razors; that for scissors, pen-knives, &c., will be comprised between 470° and 490°, and be attended by a full yellow or brown tint. Swords and watch-springs require to be

softer and more elastic, and must be heated to  $550^{\circ}$  or  $560^{\circ}$ , or until the surface becomes deep blue. Attention to these colors has now become of less importance, as metal baths are often substituted for the open fire in this operation. (Fownes.)

636. The valuable qualities of iron are too numerous and well-known to require mention, but among its many uses its value as a medicine must not be forgotten. Many springs derive their name from the iron contained in them. Chalybs is the Latin for steel; hence the derivation of *chalybeate*. There are very few waters that do not contain traces of iron. A quantity of bi-carbonate of iron,  $\text{FeO}, 2\text{CO}_2$ , the form in which it is usually contained in water, not exceeding one-fifth of a grain in a gallon, is sufficient to give it a decided taste. When waters contain much of it, they give positive signs of its presence, by leaving a yellowish-red stain of ochre on the soil over which they pass; for not only is carbonate of iron insoluble in water containing no carbonic acid, but its tendency to attract oxygen is so great, that when once it comes in contact with air, it, by its conversion into a higher state of oxydation, entirely loses its solubility. Iron-ochre is, therefore, a higher grade of oxydation than that we meet with in clay-iron-stone, or in solution in chalybeate waters.

637. A common and much used proto-salt of iron, is the PROTO-SULPHATE OF IRON,  $\text{FeO}, \text{SO}_3 + 7\text{HO}$ , commonly called GREEN VITRIOL OR COPPERAS. It is prepared by several methods, only two of which require notice. By dissolving iron in dilute sul-



phuric acid, proto-sulphate of iron is formed, and hydrogen liberated. The more common process is by partially roasting iron-pyrites, exposing it to the action of air, extracting with water and crystallization. It forms light blueish-green crystals, which are soluble in 1·6 parts of cold, and 0·3 of boiling water.

638. Of the *persalts* of iron, none is of so much household importance as common ink, by which thoughts and words are committed to paper. The basis of *black ink* are galls and a salt of iron. The iron-salt should be a mixture of protoxide and peroxide: the solution of galls should be perfectly clear and free from sediment. The iron-salt employed is the proto-sulphate of iron. By boiling, the protoxide takes up oxygen from the air, and becomes partly changed into peroxide. Black ink is, chemically speaking, PERTANNATE OF IRON suspended in water. The latter is naturally insoluble in water, but kept in suspension in the ink by means of gum-arabic. The galls contain the tannin, which unites with the peroxide of iron to form the black pertannate of iron.

639. Iron is, from improper diet, and other causes, frequently deficient in the blood; hence the use of some of its salts as a medicine. The *potash-tartrate of iron*, so much used as a tonic, is obtained by boiling the peroxide with cream of tartar.

640. *Prussian-blue*, the fine blue color used for dyeing woollen dresses, is a salt of iron. It is also used by washerwomen, under the name of *blue*, to hide the yellow color of linen.

641. SULPHIDE OF IRON,  $\text{FeS}^2$ , is of very common occurrence. It strikes fire with steel, whence its name, IRON PYRITES. It has usually metallic lustre, and a more or less golden color. It is much used in the manufacture of sulphate of iron, sulphuric acid, and alum. In some kinds of coal, too, it abounds, greatly to their injury.

642. Of all metallic substances, iron is the most universally distributed throughout nature in a state of combination. It is to be found in leaves, fruits, stalks, stems, and flowers; in the soil we tread, and in many minerals; in the flesh and blood of men and animals; and even in milk and water. And as an agent of civilization it ranks so high, that it may be safely called the most important of all metals.

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## QUESTIONS ON CHAPTER VIII.

464. Where is the grand storehouse of the metals? Are they naturally found native? Are they found in combination with one another? What are they then called? With what elements are they usually combined? Name the compounds.

465. How many metals are known to chemists? Are any of them rare? How many household metals are there? Name them. By what properties are they distinguished?

466. What is their most striking physical property? Upon what is it dependent?

467. Are metals possessed of taste? Why not?

468. Is there much difference in the specific gravity of metals? How wide a one?

469. Do the metals vary much in point of color?

470. Are metals fusible? Is there any wide difference as regards this property? Give instances. Do metals ever soften before they melt? Give an example.

471. Are metals capable of assuming the three forms of matter? Do you know one that does?

472. What do we understand by malleability? Are all metals equally malleable? Give examples.

473. In what respect does ductility differ from malleability? What important matter depends upon ductility?

474. Give proofs of the power of metals to conduct heat and electricity.

475. Do metals crystallize? What do we mean by the term? What causes crystallization? What forms of crystal are most common?

476. What are the natural compounds of the metals called? How are they usually found? What is the process for getting [the ores called? Does the mode vary? To what extent, and dependent upon what? What do we mean by ventilation? How is it accomplished?

477. What are naturally pure metals called?
478. Are metals combustible in oxygen? In what state are metals usually found?
479. Do oxides vary much? How many grades are there? What is the type of a basic oxide or salifiable base? Name the three classes of oxides. Give an example of a metal having three such compounds.
480. What do we mean by a suboxide and a superoxide?
481. What is the nomenclature of salts? What are combinations of carbonic and sulphurous acids called?
482. How are salts distinguished when the same acid forms compounds with all three basic oxides? Give an example.
483. Is this nomenclature complete? Why is it sufficient?
484. What is the Latin name for GOLD? Its equivalent? Specific gravity? Are traces of the metal commonly met with? Is it ever found otherwise than native?
485. Is it ever found in the United Kingdom? Name some places. Why is it not worked in Ireland?
486. Where are the richest mines in Europe? What do you know of them?
487. How do the negroes obtain it in Africa?
488. Do we obtain much gold from Russia?
489. Did Columbus meet with it in Hispaniola? Who had large presents of gold made to him at the conquest of Mexico? Who discovered the celebrated Potosi mine? Relate the story. Is it alone famed for gold? Is gold found in the Brazils? Give an instance of the accursed lust of gold. What is the appearance of the river in which the gold was found?
490. Does California abound in gold? Who first suggested that gold might be found in Australia? Who discovered it there? In what part was it first found?
491. In what kind of soil was it found? Were any further discoveries made? Relate what you know.
492. What is the nature of the soil in which the gold is usually found? At what depth?
493. How is the gold separated from the dross?
494. Is gold digging an easy process?

495. Where may further information be obtained?

496. When gold is embedded in stone, what process is employed?

497. What kind of a metal is gold? Why was it called king of metals? Why is the sun its symbol? Is it malleable? Is it ductile? Give an instance? How is the art of wire-drawing accomplished?

498. What is gold usually alloyed with? Why so? How much copper do our coins contain?

499. How is gold-leaf made? What is its thickness?

500. What is it used for?

501. How is electro-gilding effected?

502. Are the salts of gold important?

503. By what Latin name is SILVER known? What is its specific gravity? Its symbol? Equivalent? What name did the alchemists give to silver? Why? Is it found native? Ever otherwise?

504. How are the ores found? Is it ever found like gold?

505. How is native silver usually found? Relate what you know of the piece found at Schneeberg in Saxony?

506. Do the lead-ores of England contain silver?

507. What do you know of Hungary as a source of silver? Where is it found? How much does it yield?

508. Do the Bohemian mines afford much?

509. How much silver do the Norwegian mines yield?

510. Which are the most important Asiatic mines? How much have they afforded in the last hundred years?

511. Which is the chief country for silver? Which are the most celebrated mines? What is the name of the mountain? Describe it? Why is the river La Plata so called? How much silver do all the mines of South America yield annually?

512. How is much of the silver of commerce obtained?

513. What is the Mexican process? What is the object of straining the amalgam?

514. Is much obtained from lead-ores? What are such ores called? How obtained? What is the theory of the plan? What distinguishes base from noble metals?

515. What is the character of pure silver? Is it as hard

as gold? At what temperature does it melt? To what is the tarnishing of silver due? Is it malleable and ductile? How do you know it is the latter?

516. What objection is there to the use of silver for decorative purposes? What causes it? Can it be prevented? What is it a compound of? Is it ever found native?

517. What metal is usually alloyed with silver? How much alloy is there in our silver coin? How is the blanching of silver coin performed?

518. How is the better kind of plating performed? What is it called?

519. Is it the most usual process? How is electro-plating accomplished? What is the objection to the electro-plate lining of saucepans?

520. What oxides of silver exist? What is the formula of the protoxide? How may nitrate of silver be prepared? What is lunar caustic? Why is it called lunar? What is it employed for?

521. What is indelible ink?

522. For what other purpose is nitrate of silver employed?

523. Is chloride of silver ever found native? Where? What do mineralogists call it? How may it be prepared? What is its composition? What are its properties?

524. Upon what property in salts of silver is the process of Calotype dependent?

525. What is fulminating silver?

526. What is the Latin name for QUICKSILVER? Its eq.? Sp. gr.? Is the metal of much use? Whence the name quicksilver and hydrargyrum?

527. Why is it called mercury? What meaning do we now-a-days attach to mercurial?

528. Has quicksilver been long known? What does Pliny relate concerning it?

529. What new source of quicksilver has lately been discovered?

530. Where are the other principal mines? What do you know of the one at Idria? Does it injure miners' health? How is the ore obtained?

531. What is the process of obtaining the metal?

532. Is the same plan pursued in Spain ?
533. Describe pure quicksilver ? At what temperature does it begin to fly off in vapor ? At what temperature does it boil ? At what temperature does it become solid ? Under what circumstances does it tarnish ?
534. In what instruments is mercury employed ?
535. What are alloys of mercury called ?
536. How are looking-glasses made ?
537. What amalgam among others is used for stopping teeth ?
538. How many basic oxides has quicksilver ?
539. Describe the protoxide of mercury ? What is it composed of ? What important salt does it form with chlorine ?
540. What is the common name of the peroxide ? What are its characteristics ? What is the effect of heat upon it ? What is it employed for ? Of what color are its salts ? What is characteristic of them ? How may corrosive sublimate be prepared ? What is its proper name ? Is it soluble in water ? What is the best antidote ?
541. How much metal does cinnabar contain ? What is its proper name ? Of what is it a compound ? When employed as a pigment, what is its usual name ? How may it be prepared ? Who are the most successful manufacturers ? What is vermilion used for ?
542. Of what use is fulminating powder ?
543. What is platinum ? Why is it so useful to chemists ? What are its chief properties ? Where is it found ?
544. What is the Latin for zinc ? Its symbol ? Eq. ? Sp. gr. ? Is zinc an abundant metal ? Is it useful ? Why and for what purposes ?
545. Was zinc known to the ancients ? Under what name ? For what purpose was it employed ?
546. Who first makes use of the name zinc ? Was it common in the sixteenth century ? Has it been long known in India and China ?
547. Does zinc occur native ? In what forms of combination does it occur ?
548. Which compound is preferred for obtaining the metal ?

How is the process conducted? Upon what principles does it depend? What is a muffle?

549. Describe the properties of zinc? Is it not a brittle metal? How then may it be rolled into sheets? At what temperature does zinc melt?

550. What is the commercial name of zinc? What is the extent of the annual produce of Silesia?

551. By what process is iron coated with zinc? What is such zinced iron called?

552. What other important process does zinc subserve?

553. What oxides has zinc? What properties has the protoxide? What is its composition? Of what color are its salts? What is the characteristic of its soluble salts?

554. What is the commercial name of carbonate of zinc? Of what use is it? What is it composed of? What are its properties?

555. What is the common name for sulphate of zinc? What are its properties? How much water of crystallization does it contain? In what process is this salt largely formed? State the nature of the change.

556. What is sulphide of zinc? What is it composed of? What is blende? What other name has it? Is it ever employed in the manufacture of zinc? How?

557. For what commercial purpose is oxide of zinc employed? Why is it preferable to white lead?

558. What is the Latin name of LEAD? What is its symbol? Equivalent? Sp. gr.? Is it abundant? Only second to what metal? What great physical property does it possess? Hence its suitability to what purposes?

559. What is the name of the chief ore of lead?

560. Is lead abundant in England? In what counties? As what?

561. Does lead-ore ever contain silver-ore? In what combination? What is silver-bearing lead-ore called? How is lead obtained from its ore? What furnace is used? Give a description of it?

562. Can you give an idea of the manner in which the sulphate and sulphide re-act upon one another?



563. How much lead-ore do the mines of Great Britain furnish?

564. What is the character of the metal?

565. Were lead pipes ever used of old? Has soft water any effect upon lead? What is it in the water which injures the lead? Does hard water act upon lead?

566. What name did the alchemists give to lead? What symbol?

567. How many basic oxides of lead are there?

568. What is the character of the protoxide? What is litharge? In what respect does massicot differ from litharge? Of what color is the pure protoxide? What color are its salts?

569. What is the common name for carbonate of lead? How is commercial carbonate prepared? What is the theory of the process? What are the properties of carbonate of lead? Is it a poisonous salt? Soluble in pure water? Can it ever be taken up by water? Is it then safe to keep soft water in leaden cisterns or pipes?

570. What is sugar of lead in chemical language? What is it composed of? What is goulard water?

571. Of what color is chromate of lead? What is it used for? What is chromium? Whence the name?

572. How is red lead prepared? What is it composed of? What is it used for?

573. What is sulphide of lead? What are its properties? How may it be distinguished from the metal? Why does lead-paint tarnish?

574. What is type-metal? Why is it employed?

575. What is the Latin name for TIN? What its symbol? Eq.? Sp. gr.? Has the metal been long known? What ancient people traded with us for tin? Where else is tin found?

576. Under what influence did the alchemists imagine tin to be placed? What metal did they try to transmute it into?

577. What is the principal ore of tin? Does it occur in any other form?

578. What is the oxide called in Cornwall?

579. Where in Cornwall are the chief tin mines?

580. Give a description of the mechanical part of the process of preparing the ore?

581. What is the name of the vats in which the ore is washed?

582. What is the object of roasting the ore? How is the oxygen of the oxide got rid of? Of what does the slag consist?

583. What is further done to the impure metal?

584. Into what sized blocks is the metal cast? What are these blocks called?

585. Where are the largest stream-tin works? Why are they so called?

586. What two kinds of tin are sold? Which is the purest?

587. What color is pure tin? Why does it crackle when twisted? Is it malleable?

588. Is tin much acted upon by the air? At what temperature does it melt?

589. How is common gilt-paper made?

590. Does tin combine with oxygen? In how many proportions? What is putty-powder? What is it used for? How is it prepared?

591. What is the composition of binocide of tin? Why is it important? How much tin does the world furnish annually? How much does England alone supply?

592. What is the purple of Cassius?

593. In how many proportions does sulphur unite with tin? Which is the only important one? Were the alchemists acquainted with it? What use is now made of it?

594. Are any of the alloys of tin important? Name them.

595. What is the Latin name of COPPER? Its symbol? Eq.? Sp. gr.? Whence is the name derived? Of what is the *æs* of the ancients an alloy?

596. Does copper occur native?

597. In what form is it abundant? What is the most important ore? What is it usually a compound of? Where are mines of it to be found?

598. In what parts of the world are copper-ores found? Where is the chief mine of Sweden?

599. Where is the process of reduction carried on extensively? Why is the ore roasted? In what kind of a furnace? Why is sand mixed with the roasted ore? Which metal is to be got rid of? What is the last part of the process?

600. What color has copper? Has any other metal the same color? What are the properties of copper. At what temperature does copper melt?

601. To what purposes is copper put? Why is it employed for musical instruments?

602. Is copper used for money? How many pence are coined out of a pound?

603. In how many proportions does copper unite with oxygen?

604. What is the red oxide composed of? What are its uses and properties?

605. What oxide forms important salts? What is its common name? Under what circumstances is it formed? What color does it give to glass?

606. Of what color are its salts? Are they poisonous? Why should saucepans be kept very clean? Of what nature is the compound formed upon copper in moist air?

607. What is malachite? Where is it found?

608. Of what color is sulphate of copper? What is it composed of? Is it much used in the arts?

609. What of acetate of copper? What is its common name? What color does a little verdigris communicate to pickles? Should they not be rejected?

610. What is copper-pyrites composed of? Of what color is it?

611. Of what color is the ordinary sulphide?

612. Are any alloys of copper important? Name a few of them?

613. Is NICKEL ever alloyed with copper? Where is it found? For what is it employed?

614. What is the Latin name of *iron*? Its symbol? Eq.? Sp. gr.? Has iron been long known? In what ancient books is it mentioned? What name did the alchemists give to it?

615. Is iron ever found native? Where? What is meteoric iron?

616. What are the sources from which iron is usually made?

617. What combination of oxides forms a most valuable ore? What is its common name? Why given? What is its composition?

618. What is hæmatite? Where does it abound? What is it used for?

619. What does the hydrated hæmatite consist of? Which oxide is most abundant?

620. Why is clay-ironstone so called? Whence do we obtain our chief supplies? In what form is the iron contained?

621. What is carbonate of iron composed of?

622. Is English iron made from a pure carbonate? What is it mixed with?

623. What is the process of smelting? What change does the clay-ironstone undergo in roasting? With what substances is the roasted ore mixed? Describe the blast-furnace. What changes go on, in the heated mass of ores? What gases escape? Of what nature is the slag? Why does it swim upon the metal?

624. What is the cast-iron called?

625. How much metal may be obtained per week from a good furnace? How much metal does the ore average?

626. How much air is thrown into the furnace every twelve hours?

627. How many kinds of cast-iron are there? At what temperature does it fuse?

628. Does grey cast-iron ever contain phosphorus and manganese?

629. How is wrought-iron made? What is the process called?

630. In what respects does wrought-iron excel? When is it employed?

631. Of what color is pure iron? At what temperature does it melt? How is so great a heat ascertained? How are masses of iron joined together? By what process?

632. What curious property is possessed by iron?

633. Does iron undergo change in dry air? In pure water?

634. But in moist air? In common water? What is the change called? How may the rusting of polished iron be prevented?

635. How is steel made? In what does it differ from iron? What is the product called? How is steel tempered? Has temperature anything to do with the color of manufactured articles? What?

636. Is iron useful in medicine? Is it contained in water? In what form?

637. What is green vitriol? How may it be prepared? What properties have the crystals?

638. Which persalt of iron is of most importance? What is ink? Is pertannate of iron naturally soluble in water? How then is it kept in suspension?

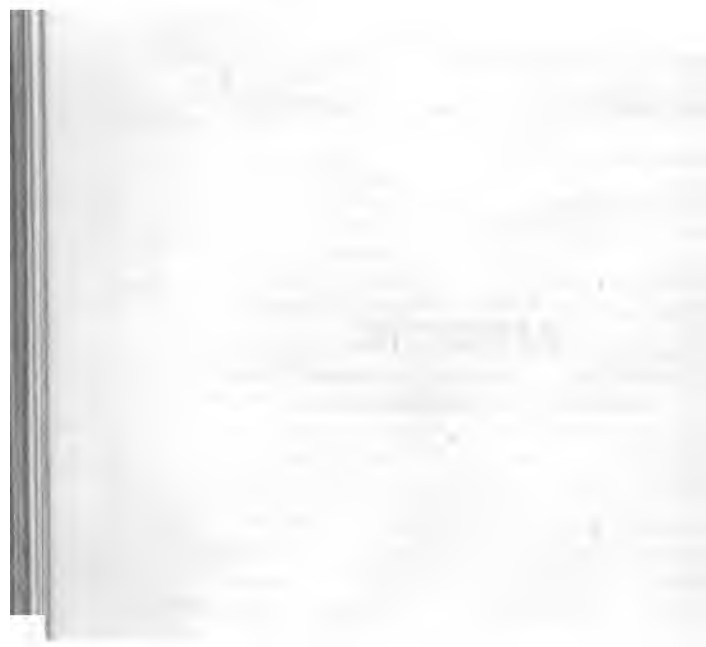
639. Why is iron ever used in medicine? What common salt of iron is frequently administered?

640. What is prussian-blue employed for?

641. What is the common name for sulphide of iron? What are its properties? Is it ever contained in coal?

642. Is iron much distributed throughout nature?

## APPENDIX.



## SUGGESTIONS

### FOR EXPERIMENTS.

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CHEMISTRY is a science so dependent on experiment, that it may be averred that a man may expend a lifetime in reading about it, without attaining to any satisfactory knowledge on the subject. We may read about the changes which the air undergoes in the processes of respiration and combustion—we may hear that a burning candle is changed into water and carbonic acid—we may see a blue-bell on the solitary heath become red during a thunder-shower;—but how much more deeply do such facts become impressed upon the mind, when we can prove these results to be constant and ever recurring under similar circumstances.

To enable the CAREFUL STUDENT better to understand the subject-matter of Household Chemistry, the performance of the following experiments is suggested.



## CHAPTER I.

SUGGESTIONS FOR EXPERIMENTS ON THE CHEMISTRY  
OF THE ATMOSPHERE.

I. The physical properties of the air are best exhibited by the air-pump; some of them may, however, be illustrated by very simple apparatus. That the air, for instance, is a *material* substance,



Fig. 26.      and fills every space which we are accustomed to call empty, the following experiment will prove:—If a cork be fitted closely into a medicine-phial, and the tube of a funnel be inserted through the cork, water poured into the funnel will not pass into the bottle, because the latter is filled with air. But if the funnel be removed, the water by its own weight descends and expels the air.

II. Again, it is a well-known fact that the air exercises *pressure*; of this the barometer affords a good illustration. If the pressure of a confined amount of air be increased, it can be forced out of a narrow opening with considerable violence, as we see in the case of a pair of common bellows. Should there be water before this opening, the air will press it out in a thin stream. The ordinary spirit-bottle

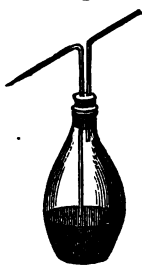


Fig. 27.

(fig. 27), so much employed by scientific chemists

for washing precipitates, is constructed upon this principle. If we blow through the shorter tube which only just dips into the neck of the bottle, we compress the air to such an extent as to force out the water through the other tube, which is drawn into a point, to give force to the stream.

III. The chemical properties of the air require fuller experimental development. It has been already stated that the air is not an element; this may be proved by the following experiment, the performance of which requires neatness of manipulation (from manus, a hand), and *especial care in the handling of the phosphorus*. The apparatus required is a deflagrating jar (fig. 9, p. 41,) a glass basin or a soup-plate, a small porcelain capsule fitted into a thin bung by means of sealing-wax (fig. 28), phosphorus, and water in a pitcher. The float con-



Fig. 28.

taining a small piece of phosphorus of *less* size than a pea, is placed on the water with which the basin or soup-plate is filled. The stopper being removed from the deflagrating jar, the latter is placed over the float



Fig. 29.

in the basin, the phosphorus in which is inflamed by means of a piece of wire heated to redness. The stopper being at *the same time* fitted into the neck of the jar, the phosphorus can of course only burn as long as the confined air lasts. (fig. 29). And inasmuch as the supporter of combustion

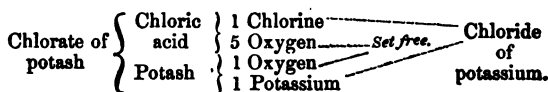
amounts to only one-fifth of the bulk of the atmosphere, the phosphorus ceases to burn as soon as the oxygen is consumed. The snow-white fumes of phosphoric acid ( $\text{PO}^5$ ) which fill the jar are soon dissolved by the water in the basin, which at once rises and fills the space previously occupied by the oxygen of the air. The colorless, tasteless, and inodorous gas which is found in the jar, after the lapse of fifteen minutes, is nitrogen. This gas does not support combustion, as a lighted taper immersed into the jar is extinguished: the experiment therefore *proves* the air to consist of *more* than *one* substance.

IV. OXYGEN, VITAL AIR, OR EMPYREAL AIR. Eq. 8; Sp. gr. 1.111. One hundred cubic inches weigh 34.6 grains. Most abundant of all elements. Colorless, tasteless, and inodorous. Ordinarily gaseous. A non-conductor of electricity. Does not change the color of flowers or litmus. Chief supporter of combustion. Oxygen was discovered by Priestley, on 1st August, 1774, and in the following year by Scheele. It may be prepared by a variety of processes.

Process 1. By heating the salt called *chlorate of potash* in a Florence flask furnished with a bent tube, and collecting the gas over water. Every hundred grains of chlorate of potash contain 40 grains of oxygen, all of which become liberated by heat. Such a quantity of salt will yield about 3 imperial pint-measures of gas.

Process 2. By heating black hyperoxide of manganese to redness in a gun-barrel.

Process 3. The best method is by mixing 3 parts of chlorate of potash with 1 of manganese, and by exposure to the heat of a spirit-lamp. All the oxygen comes from the chlorate, the manganese remaining quite unaltered. The theory of the process is illustrated by the following diagram:—



The chloride of potassium remains in the retort mixed with the manganese.

Oxygen is best collected by means of an arrangement which fig. 30 will elucidate:

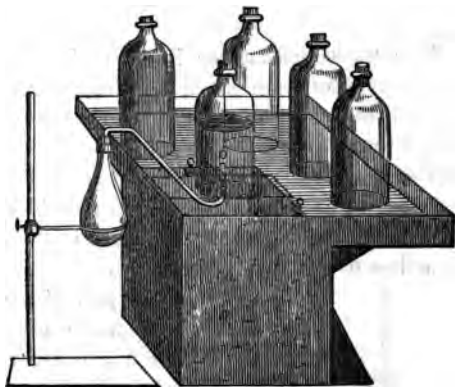


Fig. 30.

The *water-trough* or *pneumatic-trough* here depicted is most useful for collecting such gases as are insoluble, or with difficulty soluble in water. It consists of a vessel of water made of japanned

sheet-iron, provided with shelves, upon which stand the jars (filled with water and inverted) destined to receive the gas.

Gases are transferred from jar to jar with the greatest ease, by first filling the vessel into which the



Fig. 31.

gas is to be passed with water, inverting it, (fig. 31) carefully retaining its mouth below the water-level, and then bringing beneath it the aperture of the jar containing the gas. On gently inclining the latter, the gas rises into the second vessel by displacing the water in it. When the mouth of the latter is narrow a funnel may be placed in its neck, and thus loss of gas will be prevented.

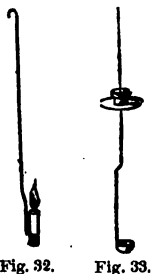


Fig. 32.

Fig. 33.

*Properties of oxygen, shewn by experiment.* a. Immerse a lighted taper (fig. 32) or a glowing taper into a jar of gas. b. Kindle a piece of sulphur in a deflagrating spoon (fig. 33) in a second bottle, it will burn with a beautiful violet-colored flame. The gas formed is sulphurous acid,  $\text{SO}^2$ . It has a most suffo-

cating odor, and first reddens, then bleaches blue litmus paper. *c.* When the spoon is *perfectly cold*, place in it a small piece of *dry* phosphorus, of the size of a pea, introduce it into a third jar of gas, and kindle by means of a hot wire. The result of the brilliant combustion is phosphoric acid, which possesses a very sour taste, and reddens blue litmus paper. *d.* Dip one end of thin coiled watch-spring into a drop of melted sulphur, and fasten the other end to a small bung; introduce it with the sulphur kindled into a fourth jar of gas; the resulting oxide of iron is insoluble, and does not redden blue litmus paper.

V. OZONE, OR MODIFIED OXYGEN, is produced during the action of an electrical machine. But a more ready way is by the action of phosphorus upon air or oxygen. *Preparation.* Take a bottle of oxygen and throw into it a small quantity of water, together with a stick of phosphorus; ozone is formed almost immediately, and may be discovered by a certain test paper, which has *no* effect upon ordinary oxygen. The paper is prepared by dipping slips of white blotting paper into a mixture of iodide of potassium and starch. Such a slip of paper dipped into a jar containing ozone becomes *blue* from the separation of iodine, which forms with the starch a compound of that color.

VI. NITROGEN, OR AZOTE. Eq. 14 : Sp. gr. 0.972. One hundred cubic inches weigh 30.16 grains. It is ordinarily gaseous, colorless, tasteless, and inodorous. Does not affect the color of flowers or of litmus. Produces no change in lime-water. Does not support combustion. Forms four-fifths of the

bulk of the air, and yet no animal can live in it. Water dissolves one and a half per cent. of the gas. Nitrogen is most easily separated from air. Thus it remains when oxygen is withdrawn from a portion of air by means of burning phosphorus, as explained at p. 297. Again, when dry air is passed over copper-turnings heated to redness in a gun-barrel, its oxygen unites with the copper to oxide, and nitrogen is liberated.

*Properties of the gas.*—A lighted taper is extinguished by nitrogen gas, and it produces no change upon lime-water, upon turmeric, or upon blue and red litmus papers. It is characterized by negative properties.

VII. CARBON. Eq. 6 : Sp. gr. 3.52. An element. Solid when in the free state. Exists under a variety of forms and in various degrees of purity. The diamond is pure carbon, usually beautifully transparent, a powerful refractor of light, and a non-conductor of heat and electricity.

Charcoal, both animal and vegetable, possesses the power of absorbing gases, of removing bad smells from putrid water, and coloring matter from some solutions. Graphite, soot, lamp-black, and coke are forms of carbon. All of them, when heated, unite with oxygen, to form—

VIII. CARBONIC ACID, FIXED AIR, or CHOKE-DAMP. Symbol,  $\text{CO}^2$ . Eq. 22. Sp. gr. 1.524. Commonly a colorless gas, may by great pressure be liquified and solidified. 100 cubic inches of the gas weigh 47.262 grains. Not a supporter of respiration or combustion. It was discovered in 1757 by Black.

The presence of carbonic acid in the air may be

proved by pouring lime-water backwards and forwards from one tumbler to another, until the colorless lime-water becomes milky-white from the deposit of carbonate of lime.

Its presence in exhaled air may be proved by breathing through a glass-tube into limewater, which in the course of a few seconds becomes white.

Exhaled air cannot support combustion. If we breathe into a jar filled with water, and inverted in the pneumatic-trough, the jar becomes filled with a gas which extinguishes a lighted taper, and precipitates lime-water.

Germination produces carbonic acid. The air in a closed pickle-jar, in which mustard seed has sprouted, extinguishes a lighted taper, and precipitates lime-water. The presence of carbonic acid in soda-water and ginger-beer may also be proved by lime-water.

*Preparation.*—But, in order to study all the various properties of carbonic acid, it is prepared by the action of spirits of salt on fragments of marble; the acid is poured in through the long funnel, and fresh portions added as often as required (fig. 34). The weight of the gas is so great that there is no need of collecting it over water. It is usually made by displacement; by its weight it expels the air, and the bottles become filled with gas.



Fig. 34.



*Properties of the pure gas.*—A colorless gas of acidulous taste and smell. *Poisonous, should not therefore be inhaled.* *a.* When prepared by burning charcoal in oxygen, the gas extinguishes flame, reddens blue litmus, and precipitates limewater. *b.* A bottle of the gas made by displacement of air, extinguishes a lighted taper. The latter becomes a test of the fulness of a jar, as it goes out the moment it is immersed into the mouth of a full jar. *c.* Carbonic acid is soluble in water, and the water, which takes up its own bulk, is possessed of all the properties of the gas. *d.* A solution of carbonic acid in water parts with the whole of it on boiling. *e.* The gas is so heavy, that a tumblerful may be poured out like water into a second tumbler, and if the experiment is successfully performed, a taper will burn in the tumbler which first contained the gas, but will be extinguished when plunged into the second. *f.* Carbonic acid may be proved to

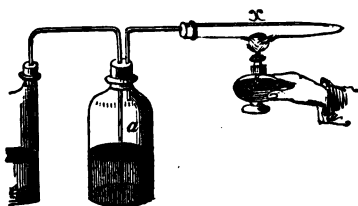


Fig. 35.

of the bottle, *a*, is to dry the gas, which is passed through oil of vitriol: in the tube, *x*, which is drawn out (not essential) place a piece of potassium of the size of a pea, and re-connect it by means of the cork with the apparatus. Evolve carbonic acid, and then apply the heat of the spirit-lamp. As soon as the

contain carbon by the following simple experiment:—Arrange the carbonic acid apparatus as in fig. 35; the object

potassium is melted, it burns with a beautiful violet-colored flame at the expense of the oxygen of the carbonic acid, the carbon of which separates as a black mass.

IX. WATER, OR OXIDE OF HYDROGEN, Symbol, HO, Eq. 9.

The fall of temperature which succeeds the fall of dew may be proved by the thermometer. The presence of water in the air may be proved by a variety of experiments, which will suggest themselves. See also p. 318.

X. HYDROGEN, OR INFLAMMABLE AIR. Symbol, H. Eq. 1. Sp. gr. 0.0696. Colorless, tasteless, and inodorous. Does not change the color of flowers or of litmus; has no effect on lime-water; inflammable, but does not support combustion. The lightest of all matter. One hundred cubic inches weigh 2.227, so that it is sixteen times lighter than oxygen, and thirteen times lighter than air. It is the standard of comparison of atomic weights. Does not exist naturally in the free state. Hydrogen was first described by Cavendish, in 1776.

*Preparation:* by a variety of methods from water. The simplest and cheapest mode of preparing hydrogen is by the decomposition of water, through the agency of zinc and oil of vitriol, as see p. 256. The arrangement is exactly the same as illustrated by fig. 34, the bottle represented being the so-called Woulfe's bottle. The gas should be collected in the pneumatic-trough over water, care being taken to reject the first bottle of gas. It is *dangerous* to bring a *light* near to the spot where

hydrogen is being evolved, as it *explodes* when mixed with air. Therefore it is that no experiment should be made with the first jar full of gas, as it is of necessity mixed with air. Again, in mixing oil of vitriol and water, another *precaution* must be observed: it is to pour the *acid* into the water, and *not* the reverse, as great heat is evolved by the chemical action which ensues between the water and the acid. About 1 part of oil of vitriol should be poured in a thin stream into 5 parts of water; such dilute acid is then fit for use. An ounce of zinc yields 676 cubic inches of the gas.

*Properties of the gas.*—*a.* No effect upon litmus or turmeric paper. *b.* The gas is so light that it



Fig. 36.

speedily escapes when a bottle full is opened to the air. *c.* On account of its lightness hydrogen is employed for filling balloons (fig. 36). In the illustration, the tube, *x*, is supposed to be filled with pumicestone to absorb moisture, and any acid that may be mechanically spirted up. *d.* A lighted taper plunged into a jar full of hydrogen inflames the gas, but is itself extinguished. *e.* When the gas is burnt either in air or oxygen, water is formed. *f.* Hydrogen may also be prepared by the action of dilute sulphuric acid upon iron-filings, an ounce of which yields 782 cubic inches; but, owing to the impurity of iron, the gas

has always a disagreeable smell.

**XI. AMMONIA, or HARTSHORN.** Symbol,  $\text{NH}_3$ .  
 Eq. 17. Sp. gr. 0.589. Colorless gas, of strong pungent taste and odor. Quite irrespirable when pure. Does not support combustion. Very soluble in water, the solution possessed of strongly alkaline taste and properties.

*Preparation.*—By heating liquid ammonia in a Florence flask (fig. 37), and displacement of air. The gas being so soluble in water, no use can be made of the pneumatic-trough. Ammonia, however, is so much lighter than air, that it is easily collected by displacement.

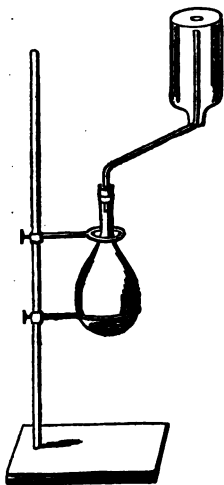


Fig. 37.

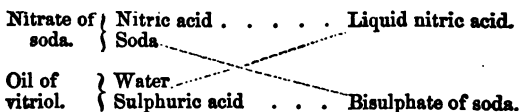
*Properties of the gas.*—  
 a. The gas blues red litmus paper, and browns yellow turmeric paper. b. It is very soluble in water, as the most simple experiment will prove. Close the mouth of a bottle full with your hand, and open up under water; the latter

will rush with violence into the bottle and almost fill it. c. Observe the effect of the gas upon a lighted taper: the taper is extinguished, and the gas at the mouth of the bottle burns with a pale yellow flame. Repeat the experiment with the same jar of gas. As atmospheric air becomes mixed with ammonia, the flame of the taper be-

comes greatly enlarged, and its light diminished.  
*d.* Pass carbonic acid gas into liquid ammonia, it is quickly absorbed, and forms a carbonate: even when saturated with carbonic acid, observe that red litmus is still blued. (Carbonic acid is so weak an acid, that it does not remove the alkaline properties of ammonia.) The addition of an acid separates the carbonic acid, as experiment will prove.

**XII. NITRIC ACID, or AQUA FORTIS.** Formed in air during thunder-storms. A very powerful acid. Until the year 1849 unknown in its anhydrous state,  $\text{NO}^5$ . The ordinary acid of commerce is very impure, generally a liquid of a yellowish color. Pure nitric acid is a colorless liquid, usually of sp. gr. 1.424. It is a true hydrate, and represented by the symbol,  $\text{NO}^5 + 4\text{HO}$ .

*Preparation.*—Fit up the apparatus as in the distillation of water (fig. 16, p. 74), employing a few ounces of common commercial nitric acid. Distil very carefully. Nitric acid is usually made from its salts, the *nitrates*, two of which, the nitrates of potash and of soda, are very important. Oil of vitriol is the acid employed to drive out the nitric acid. The reaction is thus explained:—



The process requires great caution, and should not be attempted by the mere tyro. Particulars will be found in all hand-books of chemistry.

*Properties of liquid acid.*—*a.* Very corrosive, staining the skin deep yellow, and destroying it. The stain upon dress cannot be removed. *b.* A most powerful acid, reddening litmus, and forming salts with the various metallic oxides. *c.* Expels carbonic acid from all its combinations, and may be used instead of spirits of salt to obtain it from marble; but more expensive, and requiring greater caution. *d.* Copper or iron decomposes nitric acid, separating deep orange red vapors of *hyponitric acid*.

XIII. SULPHURETTED HYDROGEN, or *rotten egg gas*, SH. Eq. 17. Sp. gr. 1·171. One hundred cubic inches weigh 36·33 grains. Product of putrefaction. Occasional constituent of air. Frequently of water. Gaseous, colorless, of most offensive

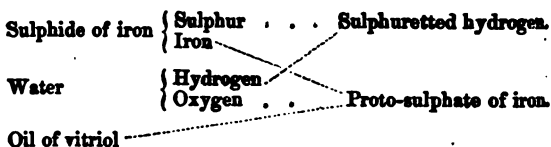


Fig. 38.

into the air we breathe.

*Preparation.*—From sulphide of iron in the same way as hydrogen (fig. 38), but the gas passed at once into a bottle or a glass full of water. The reaction is thus :—

odor. Not irritating, but narcotic. Burns in air with a blue flame, forming *sulphurous acid* and *water*. Soluble in its own bulk of water, the solution possesses all the properties of the gas. Most dangerous to health. The gas should *never* be made except in the open air, or with such arrangements as allow of no escape



*Properties of solution in water.*—*a.* Reddens litmus paper, and possesses all the properties of an acid.



*b.* Test-paper, made by dipping blotting-paper into solution of sugar of lead, is blackened. *c.* Such test-paper moistened with water detects the presence of smallest trace in air. *d.* Solution browns or blackens lead-paint from formation of sulphide of lead. *e.* A most valuable test of the presence of many metals in solution, as will be further noticed.



XIV. LAW OF DIFFUSION may be illustrated by a most simple experiment. Fill two bottles, the one with hydrogen, the other with carbonic acid, and connect them together with a tube of  $\frac{1}{2}$  of an inch bore and 2 feet long. Place them in a perpendicular position, with the bottle containing the heavy gas downwards (fig. 39). After lapse of 3 hours examine by means of lime-water. Both will be found to contain as much carbonic acid. The experiment may be varied with other gases.

## CHAPTER II.

## SUGGESTIONS FOR EXPERIMENTS ON CHEMISTRY OF COMBUSTION.

XV. CARBONIC OXIDE. Symbol, CO. Eq. 14. Sp. gr. 0.973. One hundred cubic inches weigh 30.21 grains, or as nearly as possible as much as nitrogen. According to Dumas, at least 100 times more poisonous than carbonic acid. A colorless gas, almost inodorous. Combustible, with beautiful blue flame. Plays often upon coal and charcoal fires.

*Preparation.*—The most simple plan is to pour half an ounce of oil of vitriol upon 1 dram of oxalic acid placed in a Florence flask. Put the flask upon a retort stand, heat with spirit lamp, and when the liquid boils, apply lighted paper to mouth of flask. A beautiful pale blue flame, generating carbonic acid in its combustion, appears. *Beware* of inhaling the gas.

XVI. LIGHT CARBONETTED HYDROGEN, *fire-damp, marsh-gas*. Symbol, CH<sup>2</sup>. Eq. 8. Sp. gr. 0.559. One hundred cubic inches weighing 17.41 grains. A colorless, nearly inodorous gas. Neither acid nor alkaline properties. Chief component of street gas.

*Preparation.*—Pound together quickly 1 dram of acetate of potash, 1 dram of solid caustic potash, and 2 drams of quicklime, and transfer to a Flo-



rence flask connected with an ordinary bent tube. Place it on the retort stand, apply heat, and collect the gas in bottles over water.

*Properties shown by experiment.*—*a.* No effect upon test-papers. *b.* Burns with a pale yellow flame. *c.* When it burns in contact with air, forms water and carbonic acid. *d.* Extinguishes a lighted taper, but becomes inflamed. *Beware* of any admixture of air with the gas, as a light would explode it.

**XVII. OLEFIANT GAS, OR BICARBONETTED HYDROGEN.** Symbol,  $C^2H^2$ . Eq. 14. Sp. gr. 0·986. One hundred cubic inches weighing 30·57 grains. A colorless gas, of very faint garlic odor, burns with magnificent white flame, forming carbonic acid and water.

*Preparation.*—Mix half an ounce of strong spirits of wine with 2 ounces of oil of vitriol in a Florence flask, the tube of which passes first into a bottle containing a solution of potash in water, and next into a bottle containing oil of vitriol, in a manner best discernible from fig. 40. On the careful application of heat the mixture in the flask blackens, and quantities of gas begin to arise mixed with ether, sulphurous and carbonic acids. The two latter gases are absorbed by the potash, the ether combines with the sulphuric acid, and nearly pure olefiant gas passes in a stream through the upright pointed tube of the second wash-bottle.

*Properties shown by experiment.*—*a.* A light kindles a magnificent flame of half a foot in length. *b.* A glass rod held in the light-giving portion of

the flame is blackened by the separation of carbon. *c.* A tumbler held at the point of the flame is bedewed from the separation of water. *d.* A bottle

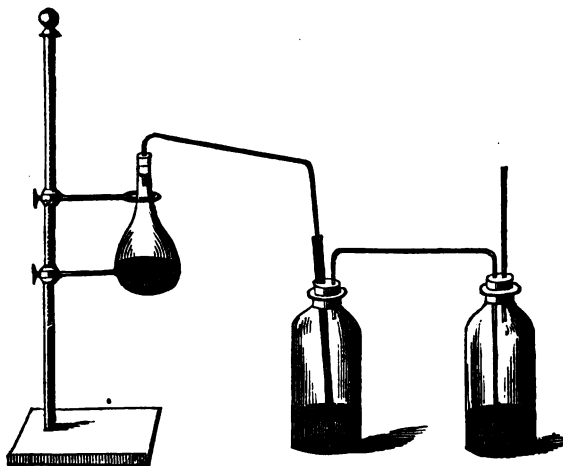


Fig. 40

held over the flame is filled with carbonic acid, the presence of which may be proved.

**XVIII. The FLAME OF GAS.** *a.* Contains carbon, the light-giving principle, which may be proved by depressing any cold substance upon the flame; *b.* in its combustion water is formed; *c.* and carbonic acid; *d.* the inner part cannot burn for want of air. (Fig. 41.)

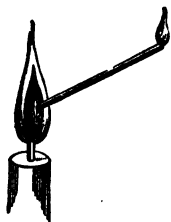


Fig. 41.

**XIX. The flame of hydrogen is**

very feeble, from absence of any solid matter. The weakest flame as regards light, is that which is produced by burning a mixture of oxygen and hydrogen. A mixture of two measures of hydrogen, and one measure of oxygen, may be safely exploded by the following arrangement. Take an oval soda-water bottle, fill it with water, and measure its contents. Take  $\frac{2}{3}$  of the water, and pour it back into the bottle: cork it, and make a mark with a file at the place where the water stands. Fill the bottle with water, place it in the trough, pass hydrogen into it, until  $\frac{2}{3}$  of the water are displaced, and then fill up with oxygen. On the application of the bottle (which, for safety's sake, should be wrapped round with a cloth,) to a lighted candle, a loud explosion takes place: the candle is snuffed out, and water is simultaneously formed.



Fig. 42.

Hemming's jet (fig. 42.) enables us to burn the gas without explosion. The brass tube is filled longitudinally with wires, the cooling power of which is so great, as to prevent the passage of flame. The attachment of a bladder filled with oxy-hydrogen, to the broad end of the jet, enables us to burn the gas with safety, and to test the enormous amount of heat generated in its combustion.

*Properties of oxy-hydrogen.*—*a.* A mixture of the two gases; *b.* burns with a blue flame; *c.* melts platinum; *d.* forms water

in its combustion; *c.* effects the most brilliant combustion of iron, steel, wood, charcoal, &c.

XX. *Flame requires a high temperature for its existence*; is cooled down by wire-gauze. In addition to experiments, mentioned in the second chapter, and suggested by what is there written: *a.* take a small square of wire-gauze, place upon it a piece of camphor of the size of a pea, heat it by spirit-lamp from below; it burns below, and not above gauze, owing to the extent to which the flame is cooled down. *b.* Take a large glass, pour half an ounce of ether into it, light your Davy-lamp, re-surround it by the gauze, and introduce it quickly into the glass. The ether-vapor will become inflamed in contact with the flame of the lamp, but the conducting, therefore cooling, power of the gauze, will prevent the passage of flame.

XXI. Several experiments will prove that the interior part of flame does not burn for want of oxygen. *a.* Pour enough ether upon a cheese-plate to cover the bottom, attach a small piece of taper of half an inch height to a piece of copper-wire, light it, and bring it quickly to the middle of the plate. The ether will be inflamed, but the candle goes out in the interior of the flame, and is only re-lighted when brought into the exterior of the flame. *b.* Set fire to a further quantity of ether, and you may pass lucifers *quickly* into the interior of the flame: they will not light until they are drawn through the exterior light-giving portion. *c.* Lay a long but thin spell of wood across the cheese-plate, pour in some fresh ether, and set it a-light.

The wood will only burn or char in the outer flame.

XXII. Hold a copper-wire at the very point of any flame, it becomes oxydized. Depress it into the interior, the wire again becomes bright.

XXIII. The oxydizing and deoxydizing portions of flame are better witnessed when the BLOWPIPE

(fig. 43) is employed. When air from the mouth is blown through the tube called the blowpipe, the *heat* of the flame is much increased by the oxygen thus introduced. It is, in fact, the heated air which produces oxydation, and not the luminous flame, for

Fig. 43. bodies must be held a little in front of the visible flame, in order to effect their oxydation.

The blowpipe is exceedingly useful for heating pieces of charcoal, for combustion in oxygen. By the chemist its use is constant.

XXIV. The *necessity of air* to all the ordinary phenomena of combustion, may be proved by such a variety of experiments, that only a few can be mentioned. *a.* The absence of air in the interior of flame, is the cause of the hollowness of flame, and its impartial combustion. Oxy-hydrogen flame is not hollow, as it possesses all the oxygen necessary for the complete combustion of its hydrogen, and is not dependent upon air. *b.* Phosphorus ceases to burn (fig. 28, p. 297) when the oxygen in a confined atmosphere is consumed. *c.* Instead of phosphorus, place a small taper in the float, light it, and watch the result. The air first expands from the heat of the flame and from the vapor

of water, as well as from the formation of heated carbonic acid gas: but soon the candle is extinguished, the carbonic acid is absorbed by the water, which rises and fills the space once occupied by oxygen. *d.* Instead of the taper, use a little ether or alcohol, which, by combustion in air, are also changed

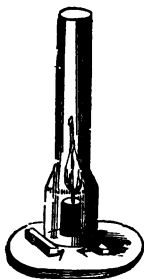


Fig. 44.

into carbonic acid and water. *e.* Place a lamp-glass over a small piece of a lighted taper (Fig. 44): the candle goes out because no fresh air is admitted from below. *f.* Admit air from below, but close the top of the chimney-glass: the lighted taper will again be extinguished, because there is no escape for the products of the combustion of the candle. *g.* Place the glass upon two pencils, or any pieces of wood, and you will find the taper will continue to burn quietly: air rushes in at the bottom, and the heated foul air escapes at the top. *h.* These glasses are to the candle or the lamp, what the chimney is to the fire-place—the narrower the chimney, the greater the draught. If we divide the chimney-glass into two channels, by a partition of card-board, (see fig. 45,) the candle continues to burn, although no air is admitted from below. A draught of air sets in from the top to the bottom, and the foul air escapes at one end of the partition: and this is easily proved, as the smoke arising from the long wick of

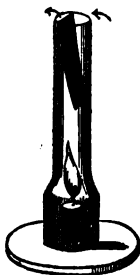


Fig. 45.

an extinguished tallow candle will be drawn inwards on one side, and expelled on the other. *i.* An extinguisher puts out the candle by cutting off the escape of the foul air arising in its combustion.

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### CHAPTER III.

#### SUGGESTIONS FOR EXPERIMENTS ON THE CHEMISTRY OF BREAKFAST.

**XXV. WATER OR PROTOXIDE OF HYDROGEN.** Symbol  $\text{HO}$ . Eq. 9. Sp. gr. 1. The standard of comparison of the weight of liquids and solids. First proved by Cavendish to be the sole product of the combustion of hydrogen. Transparent, colorless, tasteless, inodorous. Powerful refractor of light. Imperfect conductor of heat and electricity. Very incompressible. One cubic inch weighs 252.458 grains at ordinary temperature and pressure: it is 815 times heavier than air.

*Properties shewn by experiment.*—To form water by synthesis (*σύνθεσις*, synthesis, composition or putting together.) *a.* Burn hydrogen gas in air. *b.* Burn oxy-hydrogen, to prove that water is not an element. *c.* Pass steam over red-hot iron filings, (see fig. 15, p. 71). *d.* You obtain hydrogen from water. *e.* Obtain the purest natural water from

melting freshly fallen snow. *f.* Collect falling rain in a clean basin, at some distance from the house. *g.* Boil rain and snow water, the escape of bubbles of air will prove the fact that water is capable of absorbing gases. *h.* All water which has once fallen on the ground, contains various mechanical and chemical impurities. Remove

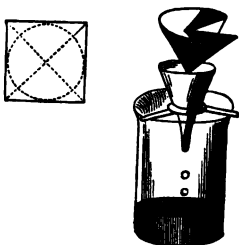


Fig. 46.

the mechanical by filtration, (fig. 46,) and the chemical by distillation (fig. 16, p. 74). *i.* The chief salts in water are common salt, gypsum, and chalk. *Common salt*, or chloride of sodium, is detected in water,

by the addition of one drop of a solution of nitrate of silver in pure water. If present, a white precipitate of chloride of silver ensues, and thus nitrate of silver is said by chemists to be a *test* of the presence of chlorine. *Gypsum* is sulphate of lime. One ounce of water will dissolve about a grain. Chloride of barium is a test of the presence of sulphuric acid, and oxalate of ammonia of lime in the gypsum. Insoluble sulphate of baryta is precipitated in the former case, and oxalate of lime in the other. Gypsum is less soluble in cold water than in boiling, and is deposited from all waters by a long-continued boiling, according as the water evaporates. *Carbonate of lime* is also found in common spring water. It is held in solution by carbonic acid, as *bicarbonate of lime*,  $\text{CaO} + 2\text{CO}^2$ . This salt loses 1 eq. of carbonic by boiling, and therefore it is that all



natural waters deposit carbonate of lime when boiled. The simplest experiment proves this. Carbonic acid passed into lime water, throws down white carbonate of lime, but an excess of the gas re-dissolves the precipitate. On boiling, the clear solution at once re-deposits carbonate of lime. *k.* Water boils at  $212^{\circ}$  under ordinary pressure and temperature, as the thermometer proves.

XXVI. TANNIN is of very frequent occurrence in plants, and imparts the well-known astringent taste. (It combines with metallic oxides, and forms salts; tannin is therefore usually called TANNIC ACID,  $C^{18} H^8 O^9, 3HO$ . It also combines with the skins of animals, forming *leather* or *tanno-gelatin*, a substance insoluble in water, and incapable of putrefaction.) A solution of perchloride of iron is a *test* of the presence of tannin whether in black or green tea, in gall-nuts, catechu, sumach, divi-divi, the rind of the walnut, &c. The young chemist may amuse himself by examining various fruits, barks, roots, with a view of proving the presence or absence of tannin. Per-tannate of iron is a blueish-black compound, and forms the dye of common *black ink*. Because of the change of color, a per-salt of iron is a test of tannin.

XXVII. CANE-SUGAR,  $C^{12} H^{11} O^{11}$ . In the root of the beet and mallow, in the sap of many trees. Sp. gr. 1.6. Unchangeable in air. Crystallizes in oblique six-sided prisms, see fig. 17, p. 85.

*Properties shewn by experiment.*—*a.* Sugar is soluble in one-third of its weight of water, and forms a clear, colorless syrup. *b.* A strong saturated solu-

tion will crystallize if set aside in a warm place. *c.* When gently heated sugar melts, and solidifies on cooling, forming a glassy amorphous mass. Properly seasoned it forms barley-sugar. *d.* Heated carefully till it browns, sugar loses 2 eqs. of the elements of water. It then forms CAMEL,  $C^{12}H^9O^9$ , so much used for coloring sherry, brandy, soups, &c. *e.* Pour oil of vitriol over a morsel of sugar in a *test-tube* (fig. 47), and heat it carefully over the spirit-lamp. Black carbon separates, and the oil of vitriol becomes dilute by combining with the water obtained from the sugar by the action of the acid. *f.* Put a lump of sugar into a cup, cover it with boiling water, and add carefully a small quantity of sulphuric acid. The same result as *e.*, without the application of heat.



XXVIII. GRAPE-SUGAR, GLUCOSE, SUGAR OF FRUITS.  $C^{12}H^{14}O^{14}$ . Abundantly diffused throughout fruits.

Fig. 47. *Properties shown by experiment.*—*a.* It may be extracted from *honey* by washing with cold alcohol, which dissolves out the syrup, and leaves the crystalline grape-sugar. *b.* It requires  $1\frac{1}{2}$  parts of cold water for solution. *c.* Its solution is therefore less sweet than that of cane-sugar. *d.* It crystallizes in granular, warty masses. *e.* When heated, it melts and loses 4 eqs. of water, and has then the same composition as starch. *f.* It dissolves in oil of vitriol, without blackening, and forms *sulpho-saccharic acid*.

XXIX. MILK, the secretion intended for the nourishment of the young.

*Properties by experiment.*—*a.* Under the microscope, milk is proved to be an emulsion. *b.* The butter may be obtained by churning or agitation. *c.* The acids of rancid butter being soluble in water, boiling several times with twice its quantity of water, will free it from its rancid taste. *d.* A few drops of muriatic acid added to warm milk, separates the casein in white flakes. *e.* If you filter the casein from the liquid, and boil the latter, it becomes slightly cloudy, from the separation of albumin. *f.* A small piece of rennet (calf's stomach) kept overnight in a spoonful of water, gives to the latter the property of coagulating new milk. Such water thrown into a quart of new milk, will, in the course of a few hours, separate casein and butter in form of a curdy mass. By pressure of the curd, we obtain the so-called cream-cheese. *g.* Sugar of milk or lactin,  $C^{12}H^{12}O^{12}$ , is obtained by evaporating whey. It crystallizes in white, translucent, four-sided prisms, of great hardness. It requires from five to six times its weight of cold water for solution.

XXX. STARCH,  $C^{12}H^{10}O^{10}$ , is found in all plants, but is most abundant in seeds and roots.

*Preparation.*—*a.* Thus, starch may be easily prepared by rasping various roots, and washing the mass upon a sieve. The torn cellular tissue remains on the sieve, while the starch passes through with the water. *b.* It may be obtained from dough by washing a spoonful in a small muslin bag: the starch settles down from the water as a white insoluble powder.

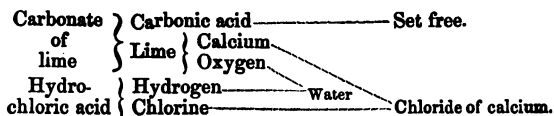
*Properties.*—*a.* Starch, whether obtained from flour, rice, tapioca, sago, cassava, arrow-root, or potatoes, is always insoluble in cold water. *b.* The starch-granules vary in form and size, as the microscope discovers. *c.* Mixed with boiling water, starch forms a thick gelatinous mass, slightly opalescent from the shreds of fine membrane which envelope each separate globule. *d.* The best test of the presence of starch is free IODINE, which forms with it a deep blue compound. When a solution of iodine in spirit is added to any compound containing starch, or when the vapor of iodine comes in contact with it, the blue compound is formed. The merest speck of iodine is sufficient for the purpose.

#### XXXI. GLUTEN or GLUTIN.

*Preparation.*—Moisten a handful of wheaten flour with sufficient water to make it into a thick paste. Enclose it in a piece of muslin, and knead it under the tap, or in a bucket full of water, as long as the water appears milky. The *starch* having been thus removed, *gluten* remains behind, mixed with vegetable fibrin, and is a viscous, tough, grey, substance. *a.* It is perfectly insoluble in water; *b.* and very adhesive, glueing the fingers together.

XXXII. The EGG-SHELL consists of carbonate of lime  $\text{CaO} + \text{CO}_2$ , and membrane.

*Properties by experiment.*—*a.* Hydrochloric acid dissolves the shell, as the following diagram proves:



*b.* If the egg be placed in a tumbler, and sufficient acid be poured upon it to float it, innumerable bubbles will be seen to escape. *c.* The escaping gas will extinguish a taper. *d.* If some of the gas be passed into lime-water, the latter will be precipitated white.

**XXXIII. ALBUMEN or ALBUMIN, the white of egg.**

*Properties by experiment.*—*a.* An egg hardens by boiling, the albumen of which sets both in the white and the yolk in the course of five minutes. *b.* The albumen of a raw egg is soluble in cold water. *c.* The solution coagulates when heated. The temperature, according to the state of dilution in which the albumin exists, varies from 145° to 170°. The temperature at which the white of an egg sets is 150°. *d.* When albumen is dried at a gentle heat, it shrinks to a very small bulk, and becomes a translucent horny mass, soluble in cold or warm water. Hot water, of course, coagulates it. *e.* Albumin, beaten up, forms a porous white froth. *f.* Blackens a silver spoon from formation of black sulphide of silver.

**XXXIV. OIL OF EGGS, is the tasty principle of an egg.**

*Properties by experiment.*—*a.* The oil may be pressed out from a hard-boiled yolk. *b.* Or it may be extracted by ether, in which it easily dissolves. *c.* It is a yellow oil, of peculiar smell and taste. *d.* Stains paper with a yellow grease spot. *e.* Burns with a bright flame.

## CHAPTER IV.

SUGGESTIONS FOR EXPERIMENTS ON THE CHEMISTRY  
OF FERMENTATION.

**XXXV. A FERMENT**, that which is light and puffy, an organic substance containing nitrogen, capable of communicating its state of change to such organic bodies as starch, sugar, lactic, glucose, &c.

*Preparation and properties of ferment shewn by experiment.*—*a.* Mix some flour with lukewarm water to a thick paste, cover it with a board, and let it remain in a warm place; it soon changes. In three or four days' time, it has become a ferment, possesses a sour smell, and throws off bubbles of gas. It has now the property of changing sugar into lactic acid, as may be proved by the addition of a piece of the dough to some sweetened water. *b.* If the dough is allowed to stand three or four days longer than in the previous experiment, it acquires a very agreeable smell, and now possesses the property of changing a solution of sugar into alcohol and carbonic acid. From a lactic acid ferment, it has become changed into a vinous ferment. It is the albumin and gluten of the flour which forms the ferment. *c.* Yeast is a most powerful alcoholic ferment. Add 1 part of fresh yeast to a solution of 5 parts of sugar in 15 parts of water : at a tempera-

ture of 75°, alcoholic fermentation is very soon set up. If the process be conducted in a pickle-bottle closed at top, and provided with a bent tube, (in such an arrangement as at fig. 34, p. 303,) the carbonic acid may be collected and examined. *d.* The addition of a spoonful of yeast to honey, dissolved in 3 or 4 parts of lukewarm water, speedily induces the formation of carbonic acid, and much spirit. *e.* Grape-juice speedily ferments when left to itself, from the presence of albumin: the juice of a few grapes readily ferments. *f.* Elderberries, currants, apples, pears, &c., when expressed, soon ferment. *g.* Candied raisins, that is, such as contain much crystallized grape-sugar, often ferment of themselves, and are possessed of a strong vinous taste and smell. They are easily obtained, and most satisfactory for experimenting upon.

XXXVI. DEXTRIN.  $C^{12}H^{10}O^{10}$ . Sometimes called *gummy starch* from its appearance, the mode of its formation, and its composition. The name is derived from *dexter*, from its action upon polarized light, twisting the plane of polarization towards the *right hand*.

*Properties by experiment.*—*a.* Formed by heating dry potato-starch to 400°. It has a yellowish color, is soluble in water, and is used in the arts under the name of *British gum*; *e.g.*, it is the sticky matter of postage-stamps. *b.* Boil for four hours 1 quart of starch in a mixture of 4 parts of water and  $1\frac{1}{2}$  part of sulphuric acid, taking the precaution to *replace* the water as it evaporates. In the course of half an hour the starch becomes changed into dex-

trin, and by continued boiling undergoes a further change. The dextrin takes up 4 eqs. of the elements of water, and forms itself entirely into GLUCOSE,  $C^{12}H^{14}O^{14}$ . In the experiment just described, the acid may be removed from solution by neutralizing with chalk, filtering to remove the sulphate of lime thus formed, and rapidly evaporating to a small bulk. In the course of a few days it solidifies to a mass of rather dark-colored, crystalline glucose, in weight exceeding the amount of starch employed. The student may purify the sugar by re-solution in water, filtration through animal-charcoal, and crystallization: he may then experiment with it, and cause a portion to undergo fermentation, as see p. 325, paragraph xxxv, c.

**XXXVII. DIASTASE.** Composition unknown, but contains nitrogen. Exists in germinating seeds and buds. Formed in malt, which contains  $\frac{1}{2}$  of 1 per cent. A white, inodorous, tasteless substance, possessed of the wonderful property of changing 2000 parts of starch into dextrin and glucose.

*Properties exhibited by experiment.*—*a.* Pour a couple of ounces of warm water upon a quarter of an ounce of pounded malt, and keep it in a warm place. In the course of a few hours the filtered solution will be found to contain the diastase. *b.* Take half an ounce of this solution and add it to some warm starch-paste, made of a quarter of an ounce of potato-starch and two ounces of water. Kept in a warm place, the starch becomes speedily dissolved, and forms a clear, transparent solution of DEXTRIN. *c.* Treat the remaining solution of dias-



tase in the same manner with starch, and keep it on the hob for several hours, and you will find the solution perfectly sweet from the presence of glucose. *d.* In the mashing process, which is indispensable both in brewing and spirit-making, it is the diastase which converts the starch into glucose. *e.* The same change may be observed in potatoes in the spring. They become first soft and mucilaginous, and then sweet: the diastase converts the starch first into dextrin, afterwards into glucose. *f.* Diastase is contained in saliva, which therefore acts as a weak ferment.

#### XXXVIII. WINE from the grape.

*Properties by experiment.*—*a.* Grape-juice becomes clouded when boiled, from separation of coagulated *albumin*. So also does a dry wine. *b.* The addition of perchloride of iron causes a black or blueish-black precipitate, proving the presence of *tannin*. This is more especially the case with astringent wines. *c.* Distil a small quantity of red wines, allowing only one-quarter of the liquid to pass over. The distillate is colorless, which proves that the coloring-matter is not volatile. The distillate burns with a pale blue flame, from the presence of much spirit of wine. *d.* Heat a spoonful of port-wine, the vapor burns with flame.

XXXIX. SPIRITS OF WINE. The strongest commercial contains 13 or 14 per cent. of water: its specific gravity is 0.835. *Proof spirit* contains 49½ per cent. by weight of real alcohol, and has a sp. gr. of 0.919 at 60°.

*Properties by experiment.* *a.* It burns with a

smokeless flame, evolving water and carbonic acid. *b.* It is volatile, and may be easily distilled; but, on account of its inflammability, the process requires great care. *c.* It is miscible with water in all proportions. *d.* It is more volatile than water, hence the wick of the spirit-lamp refuses to burn when exposed for some time to the air, for the spirit flies off, and the wick remains saturated with water. *e.* The larger the quantity of water it contains, the greater is its sp. gr. *f.* It is a great solvent of many matters which are even insoluble in water. *g.* Spirituous extracts of roots, barks, &c., form the *tinctures* of chemists and druggists. *h.* Spirituous solutions of volatile oils form the various *perfumes*, such as Eau de Cologne. *i.* Spirituous solutions of resins form the various *varnishes*. *j.* *Liqueurs* and *cordials* are solutions of volatile oils sweetened with sugar, or of bitter and aromatic substances, in spirits of wine.

**XL. ALCOHOL, OR HYDRATE OF THE OXIDE OF ETHYL.**  $C^4H^6O$ , HO. Sp. gr. 0.7938, at 60°. Colorless, limpid liquid. Very inflammable. Very poisonous.

*Preparation.*—By distilling rectified spirit, of 0.835 sp. gr., with half its weight of fresh quicklime. Pound the quicklime as quickly as possible, and put it into a retort; add the spirit, and mix by shaking. Close the neck of the retort with a cork, and leave the mixture for a few days. Distil by the heat of a water-bath, in such a manner that the retort only is heated by the boiling water, and *not* by the direct lamp-flame.

*Properties by experiment.* *a.* It attracts moisture from the air. *b.* Abstracts moisture from moist membranes, and in this way causes death when swallowed. *c.* It is highly inflammable. *d.* And whatever else has been said of common spirit, applies in every respect and with still greater force to *absolute alcohol*.

**XLI. ETHER, OR OXIDE OF ETHYL.** Symbol,  $\text{AeO}$ . Formula,  $\text{C}^4 \text{H}^6 \text{O}$ . Sp. gr. 0.72. Boils at  $96^\circ$ . Colorless, transparent, fragrant liquid, very thin and mobile. Has never been frozen. Very combustible.

*Preparation.*—Distil equal parts of rectified spirit of wine and oil of vitriol in such an arrangement as is depicted at p. 74, fig. 14. The process should be stopped as soon as the contents of the retort blacken and froth. On account of its inflammability great care must be exercised.

*Properties by experiment.*—*a.* Mixed with oxygen, and inflamed, it explodes with fearful violence. *The mode recommended in some works for preparing ozone, by the agency of ether, oxygen, and a heated glass rod, cannot with safety be recommended to any but experienced hands.* *b.* Dropped on the hand, it occasions a sharp sensation of cold, by its rapid volatilization. *c.* It is only moderately soluble in water, ten parts of which dissolve one of ether. *d.* It is easily soluble in spirits of wine and alcohol. The addition of water separates the greater part of the ether, and in this manner samples of commercial or sulphuric ether (as it is also called, although it contains no sulphuric acid) may be exa-

mined. *e.* Ether is a great solvent of oils and fat. *f.* Ether was first employed to produce insensibility to pain in severe surgical operations. *g.* It is highly inflammable, and in its combustion produces carbonic acid and water.

XLII. CENANTHIC ETHER,  $\text{AeO}$ ,  $\text{C}^{18}\text{H}^{17}\text{O}^3$ , so called from *οἶνος*, oinos, wine, and *ἀνθος*, anthos, flower, because it forms the bouquet of wines.

*Preparation.*—By the distillation of wines on a large scale. Cenanthic ether is a thin, colorless liquid. Sp. gr. 0.862. Boils at  $482^\circ$ , and is but sparingly soluble in water. Has a most powerfully intoxicating odor. It contains a true acid, the *cenanthic*.

XLIII. ACETIC ACID, OR HYDRATE OF ACETIC ACID.  $\text{C}^4\text{H}^3\text{O}^3 + \text{HO}$ . Sp. gr. 1.063. Boils at  $240^\circ$ .

*Preparation.*—By distilling finely-pounded anhydrous acetate of soda with three times its weight of oil of vitriol.

*Properties by experiment.*—*a.* Below  $60^\circ$  forms large, colorless, transparent crystals. *b.* Above  $60^\circ$  a thin, colorless liquid of very pungent odor. *c.* It blisters the skin. *d.* Its vapor is inflammable. *e.* It is miscible in all proportions with water. *f.* It unites with the various bases, and forms *acetates*. *g.* It is a stronger acid than carbonic, which it expels from its combinations. *h.* All its salts are soluble in water. *i.* When heated it evaporates readily, leaving, if pure, no residue. *k.* When an acetate is heated in a test-tube with a little sulphuric acid it is decomposed; *acetic ether* is set free, which is at

- . once recognised by its peculiarly refreshing odor.
- l. When an acetate is heated in a test-tube with *dilute* sulphuric acid, acetic acid is set free, which will at once be known by its smell. m. Vinegar owes its properties to acetic acid. A copious precipitate of white sulphate of baryta, on the addition of chloride of barium, shows *adulteration* with sulphuric acid. Mere turbidity is of no importance, as that would arise from any water containing gypsum (p. 318).

XLIV. LACTIC ACID, OR HYDRATE OF LACTIC ACID.  $C^6 H^5 O^5 + HO$ . Sp. gr. 1.215. An intensely sour, colorless, syrupy liquid. Attracts moisture, and is soluble in water, alcohol, and ether. Is contained in sauer-kraut, in meat, in the sour liquor of the starch-maker, in long-kept paste, and in sour milk. Its combinations are called *lactates*.

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## CHAPTER V.

### SUGGESTIONS FOR EXPERIMENTS ON THE CHEMISTRY OF THE DINNER-TABLE.

XLV. WATER, GLUCOSE, DEXTRIN, and STARCH, see paragraphs xxv, xxviii, xxxvi, and xxx.

XLVI. PECTIN is the jelly of fruits. Formula, according to Fremy,  $C^{64} H^{48} O^{64}$ .

*Preparation.* From the juices of most fruits by precipitation with alcohol. Thus from grated pears. Boil the juice, and filter first through linen, and then through paper; the addition of absolute alcohol (parag. xl,) yields a gelatinous precipitate.

*Properties by experiment.*—*a.* Soluble in water. *b.* Solution does not change the color of test-papers. *c.* Is changed by the smallest quantity of potash or soda into pectic acid. *d.* Dried at  $230^{\circ}$  it contains 8.7 per cent. of ash, consisting of the usual salts.

**XLVII. PECTIC ACID.**  $C^{32}H^{20}O^{28} + 2HO$ . Exists ready formed in turnips and carrots.

*Properties.*—*a.* Insoluble in water. *b.* A weak acid, forming salts with the various basic oxides. *c.* Its alkaline salts are soluble in water.

**XLVIII. CELLULOSE.**  $C^{12}H^{10}O^{10}$ . Same composition as starch, to which it is closely allied. Syn. **LIGNIN**. It is employed in the formation of cells, but must not be confounded with wood.

*Preparation.*—Fine linen or cotton well cleansed represents lignin.

*Properties by experiment.*—*a.* It is insoluble in water and alcohol, therefore tasteless. *b.* It is not acted upon by boiling water, except when the season has been unfavorable to its perfect development: hence linen and cotton wear out by washing more easily in some years. *c.* Iodine has no effect upon it. *d.* Is not even affected by very weak acids or alkalies. *e.* Oil of vitriol changes lignin into *dextrin*; add (very slowly so as to avoid heating) oil of vitriol to half its weight of lint or shreds of linen. Mix in a mortar, and let it stand a few hours. Then,

rub it up with 6 or 8 times its weight of water, warm and filter. Neutralize with chalk, and filter: the solution contains dextrin, as may be proved by the experiments suggested at paragraph xxxvi. *c.* If the liquid be boiled for three hours, previous to neutralization, and the water re-placed as it evaporates, the dextrin becomes changed into *glucose*, or *grape-sugar*. As soon as the change is complete, neutralize with chalk and filter. Linen rags thus treated, furnish more than their own weight of sugar.

XLIX. GUM, the best type of which is gum-arabic. The principle of it, is ARABIN,  $C^{12} H^{11} O^{11}$ , it is therefore *isomeric*, with crystallized cane-sugar. Gum-arabic is derived from various species of the acacia. The gum from cherry-trees, plums, &c., is called CERASIN (from *prunus cerasus*, the cherry): that from tragacanth and other gums, is called BASSORIN. In composition, they are identical with arabin.

*Preparation of arabin.*—Clear filtered solution of gum-arabic is precipitated by alcohol.

*Properties.*—*a.* Soluble in water, which becomes more or less sticky according to the quantity dissolved. *b.* More soluble in hot than in cold water. *c.* Is insoluble in alcohol. *d.* Its solution prevents the precipitation of fine powders, hence its use in inks. *e.* Its stickiness when moist, and firmness when dry, adapt it admirably to cement such light articles together as are not exposed to damp. *f.* Sulphuric acid transforms its solution first into dextrin and then into glucose. The student will easily

comprehend how such a transformation can take place.

L. MUCILAGE, is the name given to the gum obtained from quince-seed, flax-seed, the flowers of the lime-tree, &c. Its formula is  $C^{12}H^8O^{10}$ . It is soluble in water, and when heated, comports itself like arabin.

LI. OXALIC ACID,  $C^2O^3$ ,  $HO + 2HO$ . May be considered as a compound of carbonic oxide  $CO$ , with carbonic acid  $CO^2$ , joined together by water. Cannot exist except in combination with water, the removal of which causes it to separate into  $CO$ , and  $CO^2$ . Exists in a free state in the hairs of the cicer or chick-pea. United with potash, as *binoxalate of potash*, it is met with in rhubarb, in garden-sorrel, and in the wood-sorrel, *Oxalis acetosella*: then it is often called salt of lemons, although it does *not* contain the acid of lemons.

*Preparation*: either from sugar or starch.—*From sugar*—Digest 1 part of dry sugar with 8.25 parts of nitric acid, of 1.38 sp. gr. Evaporate  $\frac{1}{2}$  of the solution, and set aside the remainder to crystallize. This process yields 50 per cent of fine crystals of oxalic acid. *From starch*—Add 6 parts of dilute nitric acid of commerce, (that is, acid mixed with twice its weight of water) to 1 part of starch, and after decomposition of the acid ceases, heat gently. As soon as the red vapors cease to escape, set aside to crystallize.

*Properties by experiment*.—*a.* Colorless, transparent crystals, which are oblique rhombic prisms. *b.* The crystals are heavier than water: sp. gr. 1.507.



*c.* Soluble in 8 parts of water at 60°; *d.* in less than their own weight of boiling water. *e.* The watery solution has an intensely sour taste, and is a *fearful poison*. *f.* All its combinations with the alkalies are soluble in water. *g.* Its combinations with other oxides are insoluble. *h.* Thus the addition of a salt of lime, produces a white precipitate of *oxalate of lime*,  $\text{CaO}$ ,  $\text{C}^2\text{O}^3 + 2\text{HO}$ , in solutions of oxalic acid, or of its salts. Lime and chalk are therefore antidotes, in cases of poisoning with oxalic acid or its salts. *i.* Heat applied to a few crystals of oxalic acid in a test-tube, just covered with oil of vitriol, causes decomposition on boiling into carbonic acid and carbonic oxide. The carbonic oxide burns with a blue flame on the application of a light. (*Caution* : apply heat carefully, so as not to break the tube. Avoid inhaling any fumes, as both gases are most deadly in their effects. Hold the test-tube by means of a *test-tube holder*, as it becomes too hot to hold in the hand.) *k.* Oxalic acid drives out carbonic acid from carbonates ; it is therefore easy to prepare its salts. *l.* OXALATE OF AMMONIA,  $\text{NH}^4\text{O}$ ,  $\text{C}^2\text{O}^3 + \text{HO}$ , is prepared by neutralizing a hot solution of oxalic acid with carbonate of ammonia. The salt crystallizes in long, colorless rhombic prisms, not very soluble in cold, but very easily in hot water. Its solution is very valuable in analysis, to precipitate lime.

LII. MALIC ACID,  $\text{C}^8\text{H}^4\text{O}^8$ ,  $2\text{HO}$ , the acid of apples and pears; the chief acid of rhubarb (associated with oxalic) and the acid principle of the berries of the mountain-ash.

*Preparation*: easily from rhubarb-stalks, according to Mr. Everitt's process. The stalks are peeled, ground to pulp, and the juice expressed. The juice is heated to boiling, neutralized with carbonate of potash, and mixed with acetate of lime. Thus is the oxalic acid of the rhubarb removed and separated by filtration. To the clear liquid, solution of sugar of lead (acetate of lead) is added, as long as insoluble malate of lead continues to separate: the malate of lead is then washed on a filter, diffused through water, and decomposed by sulphuretted hydrogen. Black sulphide of lead separates, and malic acid is found in solution. The liquid is boiled, filtered, and evaporated to the consistency of syrup. Left in a dry atmosphere, it becomes converted in a few days, into a solid white mass of malic acid.

*Properties*.—*a*. Very soluble in water. *b*. Attracts water from the air, and deliquesces (becomes liquid). *c*. Solution very sour. *d*. Becomes mouldy and spoils in keeping. *e*. Its salts are called *malates*. *f*. Neither they, nor the acid solution are precipitated by lime; hence easily distinguished from oxalic acid and oxalates.

LIII. CITRIC ACID,  $C^{12} H^6 O^{11}$ ,  $3HO+2HO$ , is obtained largely from the juice of limes, lemons, and oranges: conjoined with malic acid, it is the acid of gooseberries, currants, &c. Discovered by Scheele in 1784.

*Preparation*: easily purchased. Neutralize lime-juice with chalk, dilute it with water to a paste, add gradually, while stirring, as much oil of vitriol as chalk employed, (the acid previously diluted with

five times its weight of water, the acid being poured into the water, and *not* the reverse) and apply heat. Sulphate of lime separates, and citric acid remains in solution. As soon as the former has by its own weight subsided, pour off the clear liquid, and evaporate carefully to crystallization. If the crystals are discolored, re-dissolve, filter through animal charcoal, and re-crystallize.

*Properties.*—*a.* Regular, colorless, rhombic crystals. *b.* Very soluble in water. *c.* The solution has an intensely acid and agreeable taste. *d.* Reddens blue litmus. *e.* The *citrates* of potash, soda, and ammonia are soluble. *f.* Its other salts are insoluble. *g.* Except citrate of iron, an important medicinal preparation.

LIV. TARTARIC ACID,  $C^8 H^4 O^{10}$ ,  $2HO$ . Found by Scheele originally in grape-juice. It is also the acid of tamarinds and other fruits. Amongst vegetables, it is met with in small quantities in potatoes. Is used extensively by calico-printers, and in forming effervescing draughts.

*Preparation:* entirely from the tartar, argol, or cream of tartar of commerce. It is an impure bitartrate of potash. The cream of tartar is dissolved in boiling water, and powdered chalk added as long as effervescence takes place, or until the liquid, on boiling, ceases to redden litmus. Tartrate of lime is precipitated, and neutral tartrate of potash remains in solution. By filtration, the two are separated, and the soluble salt is then thrown down by means of chloride of calcium: thus the remaining tartaric acid is obtained as tartrate of lime. This

is washed on a filter, added to the former portion, and treated with sufficient dilute sulphuric acid to decompose it. Soluble tartaric acid and insoluble sulphate of lime result. The filtered liquor, on evaporation, will yield crystals of tartaric acid.

*Properties.*—*a.* Colorless, transparent crystals, of the same form as those of oxalic acid. *b.* They do not change in air. *c.* Heavier than water, sp. gr. 1.75. *d.* Readily soluble in both hot and cold water. *e.* The solution has a pleasant acid taste, and reddens litmus. *f.* It is a stronger acid than carbonic acid, and is much used together with bicarbonate of soda, to form effervescing draughts. *g.* Its chief salt, bi-tartrate of potash, is with difficulty soluble in cold water, requiring as much as 60 times its weight.

*All the above-named compounds, with the single exception of water, are composed of C, H, and O, in varying proportions: they are always associated in nature with other nitrogenized compounds.*

LV. ALBUMIN, see paragraphs 29 and 33.

*Properties.*—*a.* To prove the presence of sulphur in albumin, dissolve a small portion of raw white of egg in a test-tube, with excess of caustic potash. Boil and add a crystal, or a drop of a solution of acetate of lead. The formation of black sulphide of lead will prove it. *b.* The presence of albumin in blood, discovers itself by heating the serum of blood in a test-tube or basin. *c.* Albumin is insoluble in pure water, but is ordinarily dissolved by a minute quantity of alkali. Boiling has the effect of extracting it. *d.* Dilute solutions of caustic potash or soda

easily dissolve coagulated albumin. *e.* Salts of copper, lead, and mercury, form insoluble compounds with albumin, hence the use of white of egg as an antidote in cases of poisoning. *f.* Alcohol precipitates albumin. *g.* The juice of meat deposits much albumin when heated.

LVI. GLUTIN is the substance upon which the value of grain depends. See p. 93, and paragraph xxxi. in appendix.

LVII. FIBRIN is found in solution in the blood.

*Preparation.*—*a.* By beating *fresh* blood with a bundle of twigs, the fibrin attaches itself to the latter, and is removed by the hand and washed with water. *b.* By washing the coagulum of blood in a cloth, until nothing but a mass of grey elastic fibres remains. *c.* By washing a thin slice of beef, until all the color and other soluble matter is removed.

*Properties.*—*a.* Although soluble in the blood during life, it coagulates spontaneously soon after the blood is withdrawn. *b.* When fresh, it forms long white elastic filaments. *c.* Being insoluble, it is quite tasteless. *d.* Carefully dried, it loses 80 per cent. of water, and becomes translucent and horny, like dried albumin. *e.* Burnt, it leaves a white ash, varying from 0·7 to 2·5 per cent. *f.* The ash consists chiefly of bone-earth, without which the formation of such nitrogenized compounds is impossible.

LVIII. CASEIN, the nitrogenized component of milk. See pp. 89, 169, pars. 173, 344; and app. par. xxix. Does not occur in any other animal fluid.

*Preparation.*—From warm fresh milk with dilute

sulphuric acid. Wash the coagulum with warm water, and then dissolve it in a dilute solution of carbonate of soda, and, if the operation has been performed in a basin, place it on a warm hob. The butter soon separates, and may be skimmed off. The solution, which contains the casein, is reprecipitated by dilute acid, and the entire process repeated several times, to get rid of the butter. The insoluble casein is at last washed with a little ether, to remove the last particles of fat.

*Properties.*—*a.* A white curd. *b.* Not soluble in pure water. *c.* Easily in water containing a little alkali. It is soda in the milk which keeps it in solution: the action of an acid is to remove the soda, and to throw down the casein. *d.* Burnt, it leaves a small amount of ash, say about 0·3 per cent. *e.* Acetic acid precipitates casein, from alkaline solutions, but not albumin. *f.* The most striking feature is its coagulation by rennet, as is well seen in the process of cheese-making. *g.* It contains 1 per cent. of sulphur: its solution in soda becomes black when boiled with acetate of lead. *h.* Unlike albumin and fibrin, casein contains no phosphorus. *i.* But, when not treated with acid, as in the case of the cheese we eat at meals, it contains no less than 6 per cent. of bone-earth.

LIX. GELATIN, see p. 164, par. 332, is generated from membranes, bones, tendons, calves' feet, &c., by the action of boiling water. Size and glue are familiar instances of impure, isinglass of pure gelatin. It has been found to consist of:

Carbon . . . . .	50·05
Hydrogen . . . . .	6·47
Nitrogen . . . . .	18·35
Oxygen . . . . .	25·13
	<hr/> 100·00

*Preparation.*—Isinglass, which forms in life the swimming-bladder of the sturgeon, dissolved in warm water, affords a pure specimen of gelatin.

*Properties.*—*a.* Easily soluble in water. *b.* Solution tasteless and inodorous. *c.* When dry, may be kept to all times. *d.* But putrifies in solution. *e.* One part in 100 parts of warm water, forms a stiff jelly on cooling, hence its use in *blanc mange*. *f.* A watery solution is precipitated by alcohol. *g.* And completely by tannin. *h.* Gelatin is used for *fining*, or clarifying beer and wine: it acts mechanically. *i.* The solidifying of turtle, mock-turtle, and other soups, is due to gelatin.

#### LX. THE ASH OF FOOD.

*Preparation:* by the action of heat. A moderate amount of heat, *i.e.* a temperature not much above that of boiling water, simply dries food. If the heat be continued below burning, the food becomes modified, but otherwise not much altered as regards weight. But at a higher temperature, it chars: changes of great importance and difficult of explanation occur: carbon and ash remain. Exposure for some time to a red-heat, in a small crucible of platinum or Berlin porcelain, expels the carbon in form of carbonic acid, and we then arrive at the ash, or incombustible matter of food.



Fig. 48.

*Properties.*—*a.* Unalterable in fire. *b.* Partly soluble in water. Boil a portion of ash in a test-tube with pure water, and filter. The filtrate (the clear solution that passes through the filtering-paper) contains salts of the alkalies, salts of potash and soda: on the filter there remain salts of the alkaline-earths, salts of lime and magnesia, together with oxide of iron. *c.* The color of the ash is more or less grey, but sometimes reddish, from the presence of oxide of iron. *d.* The amount of ash varies, according to the quality of the food, as the balance will readily indicate to the young student. The quantity is in exact proportion to the nutritive value of food, being greatest in such as contain most flesh-and-blood-forming principles. *e.* All such food as contains sulphur and phosphorus, as for instance, albumin, loses a portion when burnt: a small part of these elements will be found in the ash, in form of sulphates and phosphates.

LXI. SULPHUR, S.; eq. 16. Known from great antiquity. Its use in medicine, mentioned by Pliny. Found native in Sicily, in beds of blue clay. A pale yellow brittle solid. Sp. gr. varies from 1.97 to 2.08. It is volatile; one hundred cubic inches of its vapor weigh 206 grains.

*Properties.*—Partly purified in Sicily by fusion, and brought into commerce in form of blocks. Cast into cylindrical moulds, it forms the common roll-sulphur of the oilmen. Flowers of sulphur are made by subliming sulphur and condensing the vapor.

*Properties by experiment* —*a.* Heavier than water,



in which it sinks. *b.* Insoluble in water. *c.* Fusible. Heated carefully in a test-tube, sulphur melts at  $232^{\circ}$ , and forms a very thin-fluid, bright amber-colored liquid, which on cooling solidifies into ordinary sulphur. But, if the heat be continued, between  $430^{\circ}$  and  $480^{\circ}$ , the liquid darkens in color, and thickens so that the tube may for a moment be inverted without loss. If then poured into water, it continues for some hours soft and flexible like gutta-percha, and may be moulded into any shape. Because of this property of assuming two distinct states, or of passing into another state, sulphur is said to be **ALLOTROPIC** (from *ἀλλοτροπος*, *allotropos*, another form or shape). Thus, diamond, graphite, and charcoal are only allotropic modifications of carbon. *d.* From the temperature of  $480^{\circ}$  to  $792^{\circ}$ , its boiling point, sulphur again becomes thin and liquid. *e.* At  $792^{\circ}$  the rising vapor condenses against the sides of the test-tube. *f.* Melted in a crucible, and allowed to crystallize, it forms

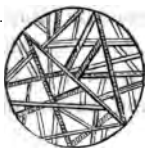


Fig. 49.

lengthened prisms. Fig. 49 shows the result. After partial cooling of the melted sulphur the crust is broken with the poker, and the yet fluid portion poured out. *g.* Sulphur is easily soluble in bisulphide of carbon.

Such a solution exposed to the air evaporates, and leaves the sulphur crystallized in form of octahedrons, with rhombic base (fig. 50). This is the form in which native sulphur occurs. On account of this property of forming two distinct kinds of crystallization, having no relation to one another,

sulphur is said to be DIMORPHOUS (from  $\delta\iota\varsigma$ , dis, twofold, and  $\mu\omicron\rho\phi\eta$ , morphe, form). Carbon has been mentioned as forming instances of allotropism; it also affords an instance of dimorphism. *h.* Sulphur is also slightly soluble in alcohol. *i.* More soluble in ether. *k.* Still more soluble in boiling turpentine.



*Fig. 50. l.* It burns in air at  $300^{\circ}$ , and forms a gas of suffocating odor, SULPHUROUS ACID,  $\text{SO}^2$ . *m.* It burns in oxygen with beautiful pale blue flame, forming the same gas. *n.* From its ready inflammability it was called brimstone, from the German word, Brennstein, a burning stone. *n.* The presence of sulphur in albumin, yolk of egg, casein, fibrin, or such like substances, is proved by boiling a small portion in a test-tube with a solution of oxide of lead in caustic-potash. Such a solution is easily prepared by precipitating the oxide of lead from a solution of acetate of lead, by means of potash, washing the precipitate, and re-dissolving it in excess of caustic potash. The student may practise a number of such experiments with various kinds of food: the presence of sulphur will be always indicated by blackening of the lead-solution.

**LXII. PHOSPHORUS.** P. Eq. 32. Never found native. Contained in food. Discovered in 1669. A wax-like solid. Sp. gr. 1.77.

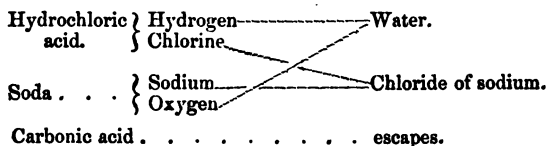
*Preparation.*—Cannot be undertaken except by an experienced student. It is prepared by the action of charcoal upon phosphoric acid at a red heat. Carbonic acid and oxide escape, and phosphorus, being volatile, sublimes and collects under water.

*Properties.*—*a.* Soft as wax, phosphorus may be cut with a knife; but, as friction inflames it, the cutting must be done *under* water. *b.* It is insoluble in water. *c.* Dry phosphorus is luminous. *d.* It inflames spontaneously at 60°. The warmth of the hand soon kindles dry phosphorus. *e.* In burning, white, choking vapors of phosphoric acid,  $\text{PO}_4$ , are produced. *f.* Burnt in a dry bell-jar, solid white phosphoric acid is produced. *g.* It burns with surprising brilliancy in oxygen, and affords the same acid. *h.* Carefully heated, with exclusion of air, it melts at 105°. *i.* It boils at 550°. *k.* Phosphorus is allotropic. The red substance that forms around burning phosphorus is allotropic. It was discovered by Schrötter, and is made by exposing phosphorus, with exclusion of air, for 50 hours to the temperature at which it boils. The student should buy an ounce of this wonderful substance: he will find it insoluble in oil, naphtha, ether, and bisulphide of carbon. It inflames at 600°, and may be safely kept in paper in the waist-coat-pocket. It burns and forms phosphoric acid. *l.* Phosphorus is very soluble in bisulphide of carbon; a few drops of such a solution poured upon paper bursts into flame as soon as the solvent has evaporated. *m.* It is also soluble in oil, naphtha, and ether. *n.* Its easy inflammability causes it to be much employed in lucifer-matches.

LXIII. CHLORIDE OF SODIUM.  $\text{Na Cl}$ . Common salt. Crystallizes in cubes, see p. 165, par. 335.

*Preparation.*—By burning the metal sodium in chlorine gas. A piece of the metal of the size of a

pea is placed in a deflagrating spoon, and heated in the blowpipe-flame to redness. Suddenly immersed into a jar containing half a pint of chlorine-gas, it burns with a bright yellow flame to chloride of sodium. May also be formed by neutralizing hydrochloric acid with carbonate of soda. The following diagram represents the change:



*Properties.*—*a.* Soluble in water, one part in  $2\frac{1}{4}$  parts. *b.* Not more soluble in hot water. *c.* Solution has a pleasant, salt taste. *d.* The crystals contain only mechanical water. *e.* Crystals *decrepitate* in the fire: the noise (crepitus) is produced by the expansive power of the steam rending asunder the crystals. *f.* Salt melts at a red heat. *g.* Is contained in the ash of plants, as a solution of nitrate of silver will prove. A white curd of chloride of silver is occasioned in any liquid containing soluble chlorides, chlorine, or hydrochloric acid.

Common salt is a singular instance of the extraordinary contraction which its two elements, chlorine and sodium, undergo in forming salt. Thus, 24 parts *by measure* contain as much as 25·8 parts of sodium and 30 parts of chlorine, a degree of compression which no mechanical power could produce.

**LXIV. CARBONATE OF SODA,  $\text{NaO}$ ,  $\text{CO}^2$ ,** in the ash, by burning, has lost its water of crystallization, see p. 216, par. 438. Common names for carbonate of soda: barilla, kelp, soda-ash, and mineral-alkali.

*Preparation.*—By burning sea-weed, washing the ash with hot water, and crystallizing the filtered solution. But chiefly from common salt, as described at p. 214.

*Properties by experiment.*—*a.* The crystals of the common salt of soda are in form of rhombic octahedrons. *b.* Contain 10 eqs. of water of crystallization, which they lose on heating to redness. *c.* Melt in their own water of crystallization. *d.* Become dry again, and then fuse in a higher temperature, losing in all 63 per cent. *e.* The crystals effloresce in air, lose their transparency, and one-half of their water. *f.* Dissolve in 2 parts of cold, and 1 part of hot water. *g.* Solution blues red litmus, and has an alkaline taste. *h.* Acids expel carbonic acid, with effervescence, forming other salts of soda. *i.* Soda, and its salts communicate yellow color to flame.

In food, the acid combined with soda is some organic acid, which on burning becomes changed into carbonic acid. Thus, for instance, tartrates, by burning, become carbonates.

**LXV. CARBONATE OF POTASH,  $\text{KO}$ ,  $\text{CO}^2$ .** Syn. Salt of tartar, pearl-ash.

*Preparation:* impure, by burning land-plants, washing the ash, and evaporating the filtered solution to dryness. Pure, by heating bi-tartrate of potash to redness. The carbonate is removed from

the charcoal, resulting from the combustion of the tartaric-acid, by solution in water and filtration. Evaporated to dryness, and kept in a stoppered bottle.

*Properties.*—*a.* A white granular salt, very difficult of crystallization. *b.* Very greedy of water, which it attracts from the air, and deliquesces. *c.* Soluble in less than its own weight of water. *d.* Solution, a strongly alkaline taste. *e.* Blues red litmus, and turns the color of the violet and the blue convolvulus to a bright green. *f.* Is decomposed with effervescence by acids, new salts resulting. *g.* Salt fuses at a red-heat. *h.* Communicates violet-color to flame. *i.* Is insoluble in alcohol.

LXVI. CHLORIDE OF POTASSIUM,  $\text{KCl}$ . Also a constituent of the ash of plants and of food. A solution of common woodash, neutralized by nitric acid, may be proved to contain chlorides by nitrate of silver. This test precipitates chlorides from their solutions in form of chloride of silver.

*Preparation.*—By neutralizing hydrochloric acid with carbonate of soda. For explanation see par. lxiii. p. 347. By burning potassium in chlorine it inflames spontaneously and burns brilliantly. It is the residue after the decomposition of chlorate of potash by heat.

*Properties.*—*a.* Crystallizes in cubes like common salt. *b.* Requires 3 parts of water at  $60^{\circ}$  for solution. *c.* Solution has a salt bitter taste. *d.* Has no effect upon test-papers. *e.* Is unaffected by heat. *f.* Insoluble in alcohol.

LXVII. SULPHATE OF POTASH,  $\text{KO}, \text{SO}^{\text{a}}$ . In wood-ash and other ashes.

*Preparation.*—By neutralizing dilute sulphuric acid with carbonate of potash, or the bi-sulphate of potash which remains in the process of making oil of vitriol.

*Properties.*—*a.* Colorless, right rhombic crystals. *b.* Decrepitate by heat from water mechanically present. *c.* Crystals fuse at a redheat. *d.* Require 16 times their weight of water at  $60^{\circ}$ , and five of boiling water. *e.* Solution of chloride of barium causes a white precipitate of sulphate of baryta, insoluble in water and acids. *f.* The solution is neutral to test-papers.

LXVIII. CARBONATE OF LIME,  $\text{CaO}, \text{CO}^2$ , is contained in the ash of plants. It is of wide distribution throughout nature. When sufficiently compact and capable of receiving a polish, it is termed *marble*: the white pulverulent formation of the upper secondary periods, is *chalk*. Those solid stone-like formations, which are neither marble nor chalk, are called *limestones*. *Calcareous spar*, *oolite* and *travertine* are forms of carbonate of lime. There are no less than 680 modifications of crystallized stone-like carbonate of lime described. *Aragonite* is a dimorphous form of calcareous spar.

*Preparation*: by pounding white marble. By precipitating chloride of calcium with white marble. The prepared chalk of druggists is well fitted for experiments.

*Properties.*—*a.* Pure carbonate of lime forms a

white powder. *b.* Insoluble in water. *c.* Heated to redness, carbonate of lime parts with its carbonic acid. *d.* Acids expel its carbonic acid; and thus may various salts of lime be produced. *e.* Carbonic acid dissolves carbonate of lime. Pass carbonic acid into lime-water; first, a white precipitate is formed, which afterwards re-dissolves as *bi-carbonate of lime*. Thus waters usually contain bi-carbonate of lime. The application of heat causes the re-deposit of carbonate of lime, by the escape of its solvent, free carbonic acid. Some waters laden with bi-carbonate of lime, deposit their carbonate as they drip in caves and cavities in rocks. Thus are *stalactites* produced. The young chemist will find by examination of such, that they effervesce with nitric and hydrochloric acids; and that the resulting salts, nitrate of lime and chloride of calcium, are soluble in water.

XLIX. SULPHATE OF LIME,  $\text{CaO}$ ,  $\text{SO}$ , in the ash of plants. Crystallizes in right oblique prisms with 2 eqs. of water: its formula is then  $\text{CaO}$ ,  $\text{SO}^3 + 2\text{HO}$ . Contained in all spring and river waters. Called *anhydrite* when found free from water. All the varieties of *gypsum* contain water of crystallization. The pure crystallized specimens are called *selenite*, and the white compact variety employed in statuary, is called *alabaster*.

*Preparation.*—By mixing a solution of any salt of lime with a soluble sulphate, and by washing the precipitated sulphate of lime. However, specimens of plaster of Paris are easily obtained.

*Properties.*—*a.* A white powder: *b.* with difficulty



soluble in water, about 1 grain in 1 ounce. *c.* Is contained in all hard waters, and is the chief cause of such hardness; see p. 23, par. 129, and appendix; p. 319, par. xxv. *d.* Gypsum heated to below  $300^{\circ}$ , loses 1 eq. of its water of crystallization. Thus dried; constitutes plaster of Paris; which, when mixed with water, rapidly becomes dry and solid by the reproduction of gypsum. *e.* Heated to redness, gypsum loses its property of setting with water. *f.* Sulphate of lime is unchangeable at redheat.

**LXX. BONE-PHOSPHATE OF LIME,  $8\text{CaO} + 3\text{PO}^5$ .**

*Preparation.*—By calcining bones, or, in a state of purity, by dissolving bone-earth in hydrochloric acid, and precipitation with ammonia. The white precipitate well washed, is bone-phosphate, with water of crystallization.

*Properties.*—*a.* Insoluble in water. *b.* Soluble in hydrochloric and nitric acids. *c.* Is the source of phosphorus and phosphoric acid.

**LXXI. PHOSPHORIC ACID.  $\text{PO}^5$ , when anhydrous.**

*Preparation.*—By burning phosphorus in dry air.

*Properties.*—*a.* A white snow-like compound. *b.* Greedy of water, with which it deliquesces, forming ordinary phosphoric acid. *c.* The liquid reddens blue litmus: *d.* and forms salts with the various bases.

**LXXII. COMMON PHOSPHORIC ACID,  $3\text{HO}, \text{PO}^5$ .  
Most important acid.**

*Preparation:* by dissolving very small pieces of phosphorus, one by one, in an evaporating basin, (fig. 51,) containing an ounce of hot nitric acid.

The experiment requires the GREATEST CARE, as accidents may occur from the violent action: nitric



Fig. 51.

acid is decomposed, part of its oxygen unites with the phosphorus to phosphoric acid, which dissolves, while orange-red vapors of hyponitric acid are copiously evolved. Further, by the action of sulphuric acid upon bones, its affinity for lime being greater, sulphate of lime and phosphoric acid result. A small quantity of phosphoric acid is easily and cheaply purchased.

*Properties.*—*a.* Forms a thick syrup. *b.* Very greedy of water. *c.* Intensely, but agreeably acid. *d.* Reddens blue litmus. *e.* Expels carbonic acid from all its combinations, and forms phosphates. *f.* Does not disorganize the skin. *g.* Heated for several days to  $415^{\circ}$ , it loses water, and is then called *pyrophosphoric acid*,  $2\text{HO}, \text{PO}^5$ . Still further heated, it loses another eq. of water and becomes changed into *metaphosphoric acid*,  $\text{HO}, \text{PO}^5$ . The common *glacial* phosphoric acid, which is so-called from its resemblance to ice, is metaphosphoric acid.

Phosphate of soda is to be found in the blood: phosphate of lime and magnesia in bone-earth, as well as in the ash of grain. Phosphoric acid and phosphates form most indispensable ingredients of animals and vegetables: phosphates are to be met with in all fertile soils.

LXXIII. PEROXIDE OF IRON,  $\text{Fe}^2 \text{O}^3$ , present in the ash of food, but more especially in blood-ash. Experiments will be suggested in chapter viii.

## CHAPTER VI.

SUGGESTIONS FOR EXPERIMENTS ON THE CHEMISTRY  
OF GLASS, CHINA, AND EARTHENWARE.

**LXXIV. SILEX, SILICA, SILICIC ACID,  $\text{SiO}_2$  ; eq. 46.5.** In the various forms and appearances of quartz, constitutes a very large proportion of the solid crust of the globe, and is the chief constituent of a vast number of minerals. When violet-colored it is called *amethyst*: when red, *rose-quartz*.

*Preparation of the insoluble modification.*—Pounded rock-crystal. Or pounded river-sand boiled with hydrochloric acid, and well washed.

*Properties.*—*a.* White gritty powder. *b.* Insoluble in water and acids. *c.* Heavier than water, sp. gr. being 2.69. *d.* Infusible in the hottest furnace. *e.* Though the feeblest acid at common temperatures, it is a powerful acid at high ones. Thus in glass-making it expels carbonic acid from carbonates.

*Preparation of the soluble modification.*—1. By fusing pounded sand with four times its weight of dry carbonate of soda, dissolving when cold in dilute hydrochloric acid, filtering and washing. 2. By passing fluoride of silicon,  $\text{Si F}_3$  into water. For this purpose, take a Florence flask, and put into it about 2 drams of fluor spar, 2 drams of sand, and 1 oz. of oil of vitriol. Adapt a gas delivery-tube,

by means of a perforated cork, and apply heat. (Fig. 52.) If the tube be passed into water, gela-

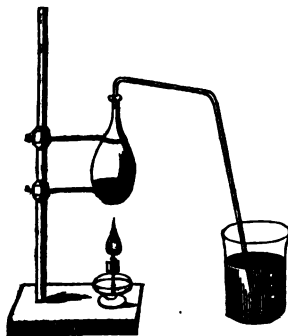


Fig. 52.

tinous silica separates in a most beautiful form. The gas is decomposed into silica and hydrofluosilicic acid.

*Properties.*—*a.* Soluble in water and acids. *b.* Separates in form of jelly from strong solutions. *c.* Unites easily with alkalis to form silicates. *d.* Once evaporated to dryness, returns

to the insoluble modification. *e.* Infusible in fire. *f.* Fusible in an alcohol flame, through which a stream of oxygen is passed. *g.* Easily fusible in oxy-hydrogen.

#### LXXV. CARBONATES OF POTASH, SODA AND LIME.

See App. pars. lxiv. lxv. and lxviii.

LXXVI. LIME, or OXIDE OF CALCIUM,  $\text{CaO}$ , eq. 28. Syn. quick-lime, live-lime, and caustic lime.

*Preparation:* by heating pure carbonate of lime to redness. Thus,  $\text{CaO}$ ,  $\text{CO}^2$  becomes  $\text{CaO}$ , and  $\text{CO}^2$  is set free. Also by heating a splinter of white marble before the blowpipe. On the large scale in lime-kilns.

*Properties.*—*a.* A white substance easily pulverized. *b.* Heavier than water, sp. gr. being 3.16. *c.* One pint of water at  $60^\circ$  dissolves 11 grains; one pint of boiling water dissolves only 7 grains.

*d.* Such a solution of lime is called **LIME-WATER**, so much used as a delicate test for carbonic acid. It is easily prepared by slaking a couple of ounces of lime, mixing with water, agitating the mixture repeatedly, and then setting it aside in a large well-stoppered bottle, until the undissolved parts shall have subsided. Pour off the clear lime-water when required, and fill up with fresh water. *Milk of lime* is made by mixing hydrate of lime with a sufficient quantity of water to give it the consistence of cream. *e.* When lime dissolves in water, it first slakes: *i.e.*, combines with 1 eq. of HO, forming itself into HO, CaO. *f.* Lime exposed to air, attracts moisture and falls to powder. *g.* Water poured upon lime is absorbed. Subsequently combining, intense heat is evolved, and hydrate of lime, or slaked lime ensues. *h.* Lime blues moistened red litmus. *i.* It combines with silica and forms silicates. Iron slags are chiefly silicate of lime.

**LXXVII. GLASS** is a mixture of silicates.

*Preparation:* on a large scale, as described at p. 196, par. 389. By fusing carbonate of soda or potash with silica on a piece of platinum wire in the blow-pipe flame, a bead of glass may be obtained.

*Properties.*—*a.* Fusible. *b.* Insoluble in water. *c.* When melted, it is perfectly flexible and plastic through a wide range of temperature, before it becomes cooled. The student may easily learn to bend tubes and such-like, in the blow-pipe flame. *d.* Various colors may easily be given (see p. 199, par. 401) to glass, by means of minute quantities of metallic oxides.

**LXXVIII. ALUMINA,  $\text{Al}^2\text{O}^3$ , eq. 51.4.**

*Preparation:* by mixing solution of alum ( $\text{Al}^2\text{O}^3$ ,  $3\text{SO}^3 + \text{KO}$ ,  $\text{SO}^3 + 24\text{HO}$ ) with ammonia in excess. White hydrate of alumina,  $\text{Al}^2\text{O}^3$ ,  $3\text{HO}$ , is precipitated: this is washed, dried, and heated to redness.

*Properties.*—*a.* A white tasteless mass. *b.* Insoluble in water and acids. *c.* Absorbs water easily, which is easily given off by heat. *d.* Will not hold water. *e.* Is easily colored by oxides. *f.* But the hydrate is soluble in acids: from it the salts of alumina are easily prepared.

**LXXIX. SILICATE OF ALUMINA,  $\text{Al}^2\text{O}^3$ ,  $3\text{SiO}^3$ , is clay in state of greatest purity.**

*Preparation:* from china-clay, boiled with dilute hydrochloric acid, washed, dried, and heated to redness.

*Properties.*—*a.* Infusible in the fire. *b.* Insoluble in water. *c.* Not acted upon by weak acids. *d.* Oil of vitriol in boiling, dissolves alumina, and separates silica. *e.* When once heated to redness, no longer strongly retentive of water, as is the case with unburnt clays. *f.* Is easily colored by metallic oxides.

## CHAPTER VII.

## SUGGESTIONS FOR EXPERIMENTS ON SOAP AND BLEACHING.

LXXX. POTASH, SODA, FATS, and OILS used in the soap-manufacture, see pp. 210—218, pars. 424—427.

LXXXI. SOAP, a true salt.

*Preparation.*—As described in text. The power of caustic-potash and soda to dissolve fat may be easily tested.

*Properties.*—*a.* When unadulterated soluble in pure water. *b.* More soluble in hot than cold. *c.* Soluble in spirits of wine. *d.* The solution decomposed by hard water. *e.* Dry soap burns in the flame of a candle. *f.* The ash communicates a yellow or violet color to flame, according to the presence of soda or potash. *g.* Solutions of soaps are decomposed by acids, fatty acids being separated, viz., stearic, margaric, and oleic.

LXXXII. CHLORINE, Cl. eq. 36, from  $\chi\lambda\omega\rho\acute{o}\varsigma$ , chloros, yellowish-green. Discovered by Scheele in 1774, and called by him *dephlogisticated muriatic acid*. Proved by Davy, in 1810, to be an element. Sp. 2·5. One hundred cubic inches of the gas weigh 76·599 grains.

*Preparation.*—From a mixture of 2 parts of hy-

drochloric acid and 1 part of manganese in the arrangement here pictured (fig. 53). In symbols,

$\text{MnO}^2$  and  $2\text{HCl}$  yield  $\text{MnCl}$ ,  $2\text{HO}$ , and  $\text{Cl}$ .

This is the simplest method, the only necessary precaution being to take care that the manganese and acid are thoroughly shaken together before heat is applied. The gas must be developed with care, but gentle heat being applied at first. It may be collected either by displacement, or in the pneumatic-trough over water.

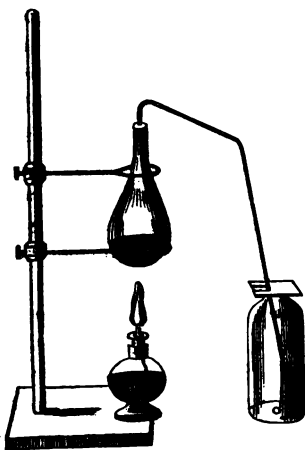


Fig. 53.

Inasmuch as chlorine is a very dangerous gas to inhale, every care must be taken to prevent its escape into the air. Chlorine may also be prepared from common salt, manganese, and sulphuric acid.

*Properties.*—*a.* A yellowish-green gas of most irritating odor, *dangerous to inhale*. *b.* Soluble in water, one volume of which absorbs two of the gas. *c.* Heavier than air by two and a half times. *d.* Supports the combustion of a taper, which burns with a feeble reddish light, throwing out volumes of soot. *e.* A strip of paper wetted with turpentine and plunged into a fresh jar of gas bursts into flame, and fills the jar with soot. (In both cases



the affinities of Cl are displayed, which are great for hydrogen, but *nil* as regards carbon.) *f*. A few grains of antimony powder thrown into a jar containing chlorine, take fire and burn with a white light: chloride of antimony results. *g*. A few leaves of Dutch gold crumpled up and thrown into chlorine, burn with flame and produce green chloride of copper. *h*. A piece of charcoal (fig. 54) wrapped up in a cage of thin brass wire, inflamed by means



Fig. 54.

of the blowpipe, and suspended in the gas: the charcoal is instantly extinguished, but the brass wire burns. *g*. A piece of sodium melted in the deflagrating spoon by means of the blowpipe, burns, when plunged into chlorine, with a beautiful yellow light. *h*. A small piece of phosphorus burns spontaneously in chlorine. *i*. Litmus-paper is instantly bleached by the gas: the green color of leaves and the color of flowers is also removed. *k*. An infusion of logwood is bleached. *l*. The solution of chlorine in water has similar bleaching effects. *m*. A jar of chlorine gas shaken with a small quantity of slaked lime, is almost instantly deprived of its gas, which combines with the lime, forming chloride of lime.

**LXXXIII. CHLORIDE OF LIME** is a mixture of HYPOCHLORITE OF LIME,  $\text{CaO}$ ,  $\text{ClO}$ ; CHLORIDE OF CALCIUM,  $\text{Ca Cl}$ ; SLAKED LIME,  $\text{HO}$ ,  $\text{CaO}$ ; and WATER,  $\text{HO}$ . Discovered by Mackintosh.

*Preparation.*—By passing torrents of chlorine into slaked lime placed in large chambers, as long as it continues to be absorbed.

*Properties.*—*a.* A white or greyish lumpy powder. *b.* When dry, has but a feeble smell. *c.* Partially soluble in water. *d.* The solution has all the bleaching properties of chlorine. *e.* These properties are very weak, without the addition of an acid. Thus, a very weak solution does not discolor blue indigo solution. But if a drop of any acid be added, the color is instantly discharged. *f.* A strip of cloth dyed with Turkey-red is bleached, if first steeped into a solution of chloride of lime, and subsequently into *very* dilute sulphuric acid (water containing  $\frac{1}{16}$  of acid). *g.* A port-wine stain is equally easy of removal by same process. *h.* No injury is done to the cloth, provided it be well washed out.

*Properties as a disinfectant.*—Most important. Foul smells are decomposed. Thus, when the air contains sulphuretted hydrogen, and a little chlorine is evolved by means of an acid from hypochloride of lime, the foul gas is removed: hydrochloric acid and sulphur result. In cases of fever it is most effective to prevent contagion. When evolution of small quantities of gas is required, a cloth steeped into a dilute solution of chloride of lime, and hung up in the room, is sufficient. For such purpose dissolve 1 part of chloride of lime in 20 parts of water, and filter, after having shaken the mixture thoroughly. Repeat the steeping as often as necessary. Or place a couple of ounces in a saucer, add sufficient water to make it into a paste, place it in the bedroom, and stir occasionally. When the smell becomes nearly imperceptible, or insufficient to disguise the air of the room, add a little vinegar, or

any weak acid. When a large quantity of gas is required in certain places, pour some hydrochloric acid upon  $\frac{1}{4}$  lb. of chloride of lime made into a paste with water, but take care not to inhale during the operation. Pour out the acid (about 2 ounces) into the basin, and leave the room instantly, taking care to shut the door. The gas will effectually do its work.

**LXXXIV. HYDROCHLORIC ACID.**  $\text{HCl}$ . Eq. 37.  
*Muriatic acid, spirits of salt, marine acid.* The gas was discovered by Priestley, in 1772.

*Preparation of the acid.*—Equal weights of chloride of sodium and oil of vitriol, brought together in a Florence flask. One ounce of acid poured upon an ounce of salt, white fumes of hydrochloric acid gas escape. Connect the flask with an ordinary bent tube and pass into water, as in fig. 52, p. 355. In this process sulphate of soda and hydrochloric acid result.

*Properties.*—*a.* Best studied in the purchased acid. When pure, a colorless, fuming liquid. *b.* Heated, it gives off hydrochloric acid gas. *c.* So, then, hydrochloric acid is a solution of the gas in water, the latter taking up 418 times its own bulk. *d.* It has then a sp. gr. of 1.195. *d.* Reddens litmus. *e.* Neutralizes the strongest basic oxides, such as potash and soda, forming **CHLORIDES**. *f.* Expels carbonic acid from all carbonates, hence its use in preparing carbonic acid from marble. *g.* Heavy white fumes of chloride of ammonium are formed whenever a glass-rod, moistened

with ammonia, is brought near to hydrochloric acid in open vessels.

**LXXXV. AQUA REGIA, OR NITRO-MURIATIC ACID.**  
 $2 \text{HCl} + \text{NO}^5$ .

*Preparation.*—By mixing 2 parts of hydrochloric with 1 of nitric acid.

*Properties.*—*a.* Dissolves gold and platinum, which neither of the acids will separately accomplish, as may be proved by experiment. *b.* Must be kept out of direct sunlight, as its most active properties are developed by heat. *c.* Care must be taken in opening the bottle containing the mixture, as it is liable to spirt from escape of gases. *d.* The mixture acts upon metals in such a way that chlorides are formed; indeed, it is solely the separation of free chlorine which causes it to act as a solvent upon gold and platinum. The nitric acid is in part decomposed; its oxygen oxydizes a portion of the hydrogen of the hydracid, water is formed, and chlorine and hyponitric acid are diffused throughout the liquid.

**LXXXVI. ANHYDROUS SULPHURIC ACID.** Syn. Glacial sulphuric acid. Symb.  $\text{SO}^3$ . Eq. 40.

*Preparation.*—Cannot be recommended to the inexperienced student. By careful distillation of Nordhausen oil of vitriol.

*Properties.*—*a.* Beautiful white silken crystals at any temperature below  $65^\circ$ . *b.* Nearly twice as heavy as water, with which it combines with violence, hissing like a hot iron. *c.* Exposed to the air, it attracts moisture and liquifies. *d.* In the absence of moisture, has no action upon litmus-

paper. *e.* By combination with water, forms common oil of vitriol.

**LXXXVII. NORDHAUSEN OIL OF VITRIOL.** Symbol,  $\text{HO}, \text{SO}^3 + \text{SO}^3$ . Eq. 89. Sp. gr. 1·89.

*Preparation.*—At Nordhausen, in Saxony, by distilling thoroughly dry green vitriol (sulphate of iron) in earthen retorts at an intense red heat.

*Properties.*—*a.* Dark-colored, fuming acid liquor. *b.* Exposed to the sun, anhydrous acid crystallizes in the neck of the bottle. *c.* A very powerful acid, destroying most vegetable and animal matters. *d.* A complete solvent of indigo. *e.* Great affinity for water, with which it combines with hissing when poured into it. (*Never pour water into the acid as an experiment; it is dangerous.*) *f.* First reddens, then chars litmus-paper. *g.* When heated, it resolves itself into common oil of vitriol and anhydrous acid, which evaporates.

**LXXXVIII. OIL OF VITRIOL; HYDRATED SULPHURIC ACID:** *English vitriol; common oil of vitriol.* Symb.  $\text{HO}, \text{SO}^3$ . Eq. 49. A definite compound of 40 parts of real anhydrous acid, and 9 parts of water. Sp. gr. 1·85.

*Preparation on the large scale.* In leaden chambers by the united action of sulphurous acid, hyponitric acid, and water upon one another. The sulphurous acid becomes oxydized at the expense of the hyponitric acid, which is changed into binoxide of nitrogen. Thus, 1 eq.  $\text{NO}^4$  oxydizes 2 eqs. of  $\text{SO}^2$ : as a result, we obtain 1 eq.  $\text{NO}^3$ , and 2 eqs. of  $\text{SO}^3$ . The presence of water is, however, essential in the process.

*Properties.*—*a.* Colorless, transparent, heavy oil-like fluid, nearly twice the weight of water. *b.* At common temperatures the most powerful acid. *c.* Expels nitric, hydrochloric, and phosphoric acids from their combinations. *d.* Has great affinity for water, with which it combines, evolving great heat. (The student must be again cautioned against pouring the water into the acid: to make dilute sulphuric acid, the acid must be poured in a thin stream into the requisite quantity of water, and complete mixture promoted by constant stirring or agitation.) *e.* Attracts moisture from air. *f.* Charrs and destroys organic matters, such as sugar, see p. 86, par. 162. *g.* Detected in all states of combination by a solution of chloride of barium. The white precipitate resulting is insoluble in water and all acids. *h.* It expels carbonic acids from all carbonates, with formation of SULPHATES. *i.* Separates chlorine from chloride of lime.

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## CHAPTER VIII.

### SUGGESTIONS FOR EXPERIMENTS ON SOME OF THE METALS.

LXXXIX. GOLD, AURUM, Au. Eq. 197. Sp. gr. 19·26. See pp. 235 to 241.

*Properties.*—*a.* Yellow, lustrous, malleable metal.

*b.* Insoluble in water. *c.* Insoluble in hydrochloric acid. *d.* Insoluble in sulphuric acid. *e.* Insoluble in nitric acid. *f.* Soluble in aqua regia, see p. 263, par. lxxxv. *g.* To test gold, rub it upon a smooth black flint, and apply a drop of aqua fortis. If the gold is pure, the bright yellow mark remains; if alloyed, it partly dissolves; if imitation, it entirely disappears. *h.* Precipitate gold from its solution in aqua regia, or, to speak more correctly, the tetrachloride of gold, by a solution of green sulphate of iron. The brown powder is gold: by mixing it, when washed and dried, with oil of lavender, the color for gilding porcelain and glass is obtained. *i.* Sulphuretted hydrogen precipitates gold from its salts in form of brown-black sulphide of gold.

XC. SILVER, ARGENTUM. Ag. Eq. 108. Sp. gr. 10.5. See pp. 241 to 247.

*Properties.*—*a.* Beautifully white, lustrous and malleable metal. *b.* Unchangeable in clean air and water. *c.* Tarnishes in foul air and water, owing to the formation of sulphide of silver. *d.* Soluble in nitric acid, with evolution of orange-red fumes of hyponitric acid gas; NITRATE OF SILVER thus obtained. *e.* Pure silver forms a clear, colorless solution with nitric acid; silver alloyed with copper, a beautiful blue solution from admixture of nitrate of copper with the nitrate of silver. Such a solution will always be obtained when a silver coin of the realm is placed in a cup with nitric acid, and set aside on a warm hob. *f.* NITRATE OF SILVER, Ag O, NO<sup>5</sup>, as purchased, is easily soluble in pure water, but with cloudiness in common water,

owing to the presence of common salt, which throws down insoluble chloride of silver. *g.* Add a few drops of solution of potash to a small quantity of sol. of nitrate of silver. A brown precipitate of PROTOXIDE OF SILVER,  $\text{Ag}_2\text{O}$ , ensues. *g.* Add a few drops of hydrochloric acid or of common salt to another small quantity of the nitrate. A white cheese-like precipitate of CHLORIDE OF SILVER,  $\text{AgCl}$ , results. *g.* Chloride of silver dried and heated in a small cup, melts, and forms *horn-silver*. *h.* The chloride exposed to light acquires first a violet, then a blue hue. *i.* Sulphuretted hydrogen precipitates silver solutions in form of brown-black *sulphide of silver*.

XCI. QUICKSILVER, MERCURY, Hydrargyrum, Hg. 202. Sp. gr. 13.56. See pp. 247 to 253.

*Properties.*—*a.* A fluid lustrous metal. *b.* Boils at  $680^\circ$ . *c.* Forms *amalgams* with gold and silver, as the student will discover by mixing gold and silver leaf with a drop. They dissolve. *d.* Such an amalgam may be used for gilding or silvering a copper coin: smeared on to a coin, and heated, the mercury is dissipated, and the gold remains firmly fixed. *e.* Like all metals, mercury expands by heat, and contracts by cold: hence its use in thermometers. *f.* If mercury be placed in a basin, with half its weight of nitric acid, and left in the cold, crystals of PROTONITRATE soon separate. In solution, we also find protonitrate, which is precipitated as black PROTOXIDE,  $\text{Hg}_2\text{O}$ , by solution of potass, and as white PROTOCHLORIDE or CALOMEL,  $\text{Hg}_2\text{Cl}_2$ , by hydrochloric acid. Calomel, moistened with potash,



blackens from separation of black protoxide, hence the name from *καλός* (*kalos*), beautiful ; and *μέλας* (*melas*), black. The solution of proto-nitrate *silvers* a copper coin when rubbed over it : the silvering is of course due to quicksilver. *g.* But if mercury be heated with nitric acid, solution of PERNITRATE OF MERCURY,  $\text{HgO}$ ,  $\text{NO}^5$  is obtained. Upon this solution, hydrochloric acid has no effect; potash produces a yellowish-red precipitate of PEROXIDE OF MERCURY,  $\text{HgO}$ . Sulphuretted hydrogen precipitates black SULPHIDE OF MERCURY,  $\text{HgS}$ . : when washed, dried, and sublimed, it yields a black-colored mass, the color of which changes by friction, into a bright red. It is then called vermilion, but has the same composition as the black sulphide, and affords a good instance of ISOMERISM, a property of many substances, which, though identical in composition, have different properties. The word is derived from the Greek.

XCII. ZINC, ZINCUM, Zn. 32. Sp. gr. 7.0. See pp. 253 to 257.

*Properties.*—*a.* Blueish-white metal. *b.* Naturally brittle, but malleable between  $250^\circ$  and  $300^\circ$ . *c.* Melts in the fire at  $773^\circ$ . *d.* Burns in a good fire with a magnificent green light, generating OXIDE OF ZINC,  $\text{ZnO}$ . *e.* The oxide is yellow when hot, white when cold. *f.* It is easily soluble in hydrochloric, nitric, and sulphuric acids, forming chloride, nitrate, and sulphate of zinc. *g.* The metal is a source of hydrogen, as see pp. 256, 257, and p. 305, par. x. *h.* The solution of SULPHATE OF ZINC obtained in the making of hydro-

gen, is precipitated by potash in form of a bulky white HYDRATED PROTOXIDE,  $\text{HO, ZnO}$ . Excess of potash re-dissolves it. Ammonia gives same results.

i. Carbonate of soda throws down from all solutions of salts of zinc, a white precipitate of CARBONATE OF ZINC,  $\text{ZnO, CO}^2$  mixed with *hydrate*,  $\text{HO, ZnO}$ . k. Sulphuretted hydrogen precipitates *white* SULPHIDE OF ZINC,  $\text{ZnS}$ , hence the value of zinc paints, which never tarnish in the most impure air.

XIII. LEAD, PLUMBUM, Pb. 104. Sp. gr. 11.45. See pp. 257 to 263.

*Properties.*—a. A soft blueish malleable metal. b. Melts easily in the fire at  $612^\circ$ . c. Slowly oxydizes in moist air. d. Melted in air, it oxydizes rapidly, and forms the PROTOXIDE,  $\text{PbO}$ . This oxide melts at a red heat, and is known in commerce by the name of litharge. e. Heated in a small iron ladle with  $\frac{1}{4}$  of its weight of chlorate of potash, the oxide becomes changed into RED OXIDE OR RED LEAD,  $\text{Pb}^3\text{O}^4$ . f. The oxide dissolves easily in hot nitric acid, forming a clear transparent solution of PROTONITRATE,  $\text{PbO, NO}^3$ . g. Lead also dissolves readily when boiled with nitric acid, being oxydized at the expense of a portion of the acid. h. Oxide of lead

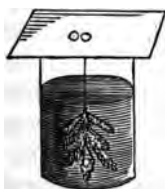


Fig. 55.

dissolves with readiness in acetic acid. ACETATE OF LEAD,  $\text{PbO, } \bar{\text{A}} + 3\text{HO}$ , is soluble in  $1\frac{1}{4}$  parts of cold water. The pleasing experiment of the *lead-tree*, (fig. 55,) is best performed in solutions of the acetate (sugar of lead). When a piece of zinc is suspended in such a

solution, it becomes oxydized at the expense of the oxygen of the oxide of lead. Acetate of zinc is obtained in solution, whilst the lead is deposited in form of beautiful plates upon the zinc. *i.* CHLORIDE OF LEAD,  $\text{PbCl}_2$  requires 135 parts of cold water for solution; hence, whenever a solution of a salt of lead is poured into pump-water, or into hydrochloric acid or common salt, a white precipitate results. *l.* Sulphuretted hydrogen precipitates all soluble salts of lead, in form of black SULPHIDE,  $\text{PbS}$ . *l.* It also decomposes all insoluble salts of lead, with a similar result: all lead paints, therefore, exposed to an atmosphere containing this gas, become blackened. *m.* Sulphuric acid or soluble sulphates produce, in all solutions of salts of lead, a heavy white precipitate of SULPHATE OF LEAD,  $\text{PbO}, \text{SO}^2$ . *n.* Solutions of potash or soda, precipitate WHITE HYDRATE,  $\text{HO}, \text{PbO}$ , which is soluble in considerable excess of the precipitants. *o.* Carbonates of potash, soda, and ammonia, precipitate lead from all solutions in form of CARBONATE OF LEAD,  $2(\text{PbO}, \text{CO}^2) + \text{HO}, \text{PbO}$ .

XCIV. TIN, STANNUM,  $\text{Sn}$ . 58. Sp. gr. 7.3. See pp. 263 to 266.

*Properties.*—*a.* White, soft, malleable metal. *b.* When bent, the metal emits a crackling sound. *c.* Melts easily in the fire at  $442^\circ$ . *d.* Alloys itself with lead, and forms *plumber's solder*, which may be made by melting together two parts of lead with one of tin. *e.* Reverse the proportions, and you obtain *fine solder*. *f.* Heated above its melting-point, tin oxydizes rapidly, and becomes changed into so-called *putty-powder*. *g.* The metal dissolves

readily in hot hydrochloric acid, forming PROTOCHLORIDE OF TIN,  $\text{SnCl}$ , which crystallizes in needles containing 2 eqs. of water. *h.* Solution of protochloride separates gold and mercury from their salts in the metallic form. It is therefore a valuable deoxygenizing agent. *i.* Solution of carbonate of potash precipitates WHITE HYDRATED PROTOXIDE,  $\text{HO}, \text{SnO}$ , from solution of protochloride. The carbonic acid escapes with effervescence, having no affinity for the oxide of tin. *k.* Trichloride of gold, added to a dilute solution of protochloride of tin, gives rise to the most characteristic compound of tin, which, on account of its color, is called *Purple of Cassius*. It is employed in enamel-painting. *l.* Sulphuretted hydrogen precipitates coffee-brown PROTOSULPHIDE OF TIN,  $\text{SnS}$ . Addition of nitric acid to a solution of the protochloride, changes it into PERCHLORIDE OF TIN,  $\text{SnCl}^2$ . *m.* This salt is also formed by gently heating tin with aqua regia. As chemical action is very violent, the operation is best performed in a porcelain basin. See par. lxxii. *n.* Soda, or potash, added to solutions of the perchloride, produce white precipitates of the HYDRATED PEROXIDE, soluble in excess of the precipitant. *o.* Alkaline carbonates produce the same result, but the resulting peroxide is not soluble in an excess of precipitant. *p.* Sulphuretted hydrogen produces a yellow precipitate of PERSULPHIDE OF TIN,  $\text{SnS}^2$ .

XCV. COPPER, CUPRUM, Cu. 32. Sp. gr. 8.96. See pp. 267 to 271.

*Properties.*—*a.* A malleable, ductile, yellowish-red metal. *b.* A conductor of heat and electricity.

*c.* Unchangeable in dry air. *d.* Becomes covered with a green crust of carbonate of copper in moist air. *e.* Heated to redness, becomes covered with a black coating of PROTOXIDE,  $\text{CuO}$ . *f.* Dissolves in nitric acid with evolution of BINOXIDE OF NITROGEN,  $(\text{NO}^2)$ : the copper is oxydized ( $\text{CuO}$ ), and enters into combination with a portion of undecomposed nitric acid ( $\text{NO}^3$ ) PROTONITRATE OF COPPER,  $\text{CuO}$ ,  $\text{NO}^3 + 3\text{HO}$  being formed. *g.* Does not dissolve in dilute sulphuric acid. *h.* But dissolves easily with hot oil of vitriol. The acid ( $\text{SO}^3$ ) is partly reduced to sulphurous acid ( $\text{SO}^2$ ): the oxygen it loses combines with the copper ( $\text{CuO}$ ) and SULPHATE OF COPPER ( $\text{CuO}$ ,  $\text{SO}^3 + 5\text{HO}$ ) results. See p. 269. This salt is much used in electro-typing, and the

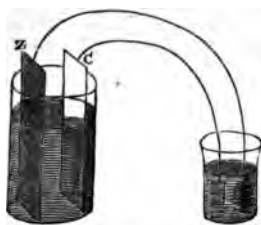


Fig. 56.

apparatus to be recommended for experiments, is the one figured here. The solution of sulphate of copper must be saturated, and if the student remembers that this salt is soluble in 4 parts of

cold water, he will discover that he must purchase 5 oz. for every imperial pint of water. Information on this subject of depositing the various metals, can be obtained in any of the small works on the electrotype. *i.* A knife-blade becomes covered with a coating of metallic copper, whenever it is dipped into a solution of a salt of copper. This is owing to the greater affinity of oxide of iron for acids: a salt of iron is formed, and an equivalent of copper

precipitated. *k.* Iron or steel may thus be employed to remove copper from its solutions. *l.* Ammonia throws down the HYDRATED OXIDE ( $\text{HO}, \text{CuO}$ ) in form of a blueish-white precipitate, which re-dissolves in an excess, to a magnificent azure-blue. *m.* Yellow prussiate of potash detects the merest trace of a salt of copper when in solution, by the production of a port-wine-colored precipitate. *n.* Solution of carbonate of soda precipitates BASIC CARBONATE OF COPPER, in form of a pale blue flocculent substance. *o.* Oxide of copper dissolves in hydrochloric acid ( $\text{HCl}$ ), and forms a splendid green solution of CHLORIDE OF COPPER, ( $\text{CuCl} + 2\text{HO}$ ), which colors flame green. *p.* Potash precipitates the hydrated oxide from all its solutions; on heating the precipitate in a test-tube, it loses its bulkiness and original color, and becomes changed into black oxide. *q.* Sulphuretted hydrogen precipitates black SULPHIDE OF COPPER, ( $\text{CuS}$ ).

XCVI. IRON, FERRUM,  $\text{Fe}$ . 28. Sp. gr. 7.8. See pp. 271 to 281.

*Properties.*—*a.* White, lustrous, soft, and tough, when pure. *b.* Iron-wire the toughest of all metals, and will bear the greatest weights. *c.* Cannot be fused in any ordinary furnace. *d.* Does not oxidize in dry air. *e.* But easily in moist air, when it is said to rust. *f.* Dilute sulphuric acid readily dissolves iron with decomposition of water ( $\text{HO}$ ); a green solution of PROTOSULPHATE OF IRON ( $\text{FeO}, \text{SO}^3 + 7\text{HO}$ ) results, and hydrogen ( $\text{H}$ ) is evolved. Such a solution, and such a salt contains the PROTOXIDE ( $\text{FeO}$ ). *g.* Potash, soda, and ammonia throw down

iron from its solutions in form of white HYDRATED PROTOXIDE ( $\text{HO, FeO}$ ), which instantly becomes green, and ultimately, by further oxydation, red-brown. *h.* Carbonates precipitate white PROTO-CARBONATE ( $\text{FeO, CO}^2$ ), which also rapidly changes color through oxydation, and parts with its carbonic acid. *i.* In recently made solutions of protosulphate of copper, ferro-cyanide of potassium (yellow prussiate of potash) produces a white precipitate, which rapidly changes to blue, more or less deep, according to exposure to air. *k.* Iron dissolves in nitric acid; PERNITRATE OF IRON is formed, and red fumes of hyponitric acid are evolved. This salt, which is used in dyeing, contains, of course, the PEROXIDE or SESQUIOXIDE ( $\text{Fe}^2 \text{O}^3$ ). *l.* In solutions of the per-salts, potash, soda, and ammonia precipitate the iron in form of a bulky red-brown hydrate ( $3 \text{HO} + \text{Fe}^2 \text{O}^3$ ). *m.* Soluble carbonates also precipitate the hydrate with effervescence, because no per-carbonate exists. *m.* Ferro-cyanide of potassium precipitates the peroxide in form of a magnificent blue, known familiarly as *Prussian blue*. *n.* Sulphuretted hydrogen reduces a salt of peroxide to the state of a protoxide, its hydrogen is oxydized as water, and its sulphur is precipitated. *o.* A per-salt of iron is always formed when nitric acid is added to a solution of a proto-salt. The black color produced in the process, results from a combination of a part of the remaining proto-salt with binoxide of nitrogen. As soon as all the salt is per-oxydized, the color changes from black to yellow, red fumes of hyponitric acid

being evolved. *p.* Tannin is a good test of the presence of peroxide of iron, for it produces a blue-black precipitate (or discoloration if the quantity be very small) of *per-tannate of iron*. Common ink is such a *per-tannate*. *q.* A piece of steel may be readily distinguished from iron; for, if a drop of nitric acid be let fall upon it, it will occasion a black spot, from separation of carbon, but it will have no effect upon wrought iron. *r.* The presence of iron in various kinds of food is readily proved by dissolving the *ash* (say of meat) in dilute hydrochloric acid. In the filtered solution yellow prussiate will readily detect it by the production of a blue color.

Further experiments on these metals will suggest themselves to the student; but if those which have been described above should give a taste for Chemistry, other books will be eagerly searched by the student.



## IMPORTANT ERRATA.

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- P. 23, par. 33, for 0·693, read 0·0696.  
P. 26, par. 37, for *harebell*, read *hair-bell*.  
P. 76, par. 137, for *rawn*, read *drawn*.  
P. 85, par. 160, bottom line, for *presses*, read *prisms*.  
P. 107, par. 211, seventh line, for *is*, read *are*.  
P. 109, par. 215, second line from bottom, for *vive*, read *vine*.  
P. 122, par. 249, second line, for *or*, read *and*.  
P. 157, par. 316, seventh line, for PO, read PO<sup>5</sup>.  
P. 174, par. 353, six lines from end of par. for *falls*, read *fails*.  
P. 234, par. 479, for DENTOXIDE, read DEUTOXIDE.  
P. 240, par. 500, for *stoppin*, read *stopping*.  
P. 254, par. 544, for *roofing gutters*, read for *roofing, gutters*.  
P. 269, par. 607, for CaO, read CuO.  
P. 296, par. II, two lines from bottom, for *spirit-bottle*, read *spirt-bottle*.  
P. 321, par. XXVII. c., after word *heated*, place a comma.  
P. 350, par. LXVIII, third line from bottom, for *with white marble*, read *with solution of sesqui-carbonate of ammonia*.  
P. 351, for par. XLIX, read LXIX.  
P. 352, par. marked XLIX. d. for, *loses 1 eq.*, read *loses its 2 eqs. of*.

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